The Journal of Thoracic Surgery

VOL. 25 MAY, 1953 No. 5

Original Communications

PHYSIOLOGIC STUDIES FOLLOWING THORACIC SURGERY

IV. THE MECHANISM OF THE DEVELOPMENT OF ACIDOSIS DURING ANESTHESIA

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SEVERAL recent papers have called attention to the development of acidosis during anesthesia.[1-7] Previous work from this laboratory has confirmed the development of acidosis during thoracic operations performed under Sodium Pentothal-curare anesthesia.[8] The present work is an attempt to establish the mechanism by which this acidosis develops. This paper is included in the series describing the changes which are found following thoracic surgery because it is felt that the events which occur during the surgical period best explain the findings which follow surgery.[9, 10]

MATERIAL AND METHODS

Thirteen patients (ranging in age from 18 to 53 years) were studied before, during, and immediately following thoracic surgery. The results of the immediate postoperative studies have been reported previously.[8] The preoperative work-up included an evaluation of the pulmonary function of the patients as well as the determination of control values for total ventilation, alveolar and dead-space ventilation, and the blood acid-base pattern. The pertinent preoperative data are given in Table I.

All patients were premedicated with barbiturates followed by atropine, and either morphine or Demerol. Anesthesia was accomplished by means of intravenous Sodium Pentothal. Supplementary nitrous oxide was used during the anesthesia. Closed endotracheal positive pressure respiration (manually controlled) was used throughout the period of the operation. The patient was placed on the operating table in the semiprone position. With the exception of the first three, an attempt was made to select only those patients who were to have a segmental or subsegmental resection.

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Published with approval of Chief Medical Director. The statements and conclusions published by the authors are the result of their own study and do not necessarily reflect the opinion or policy of the Veterans Administration.

Read in part before the Twenty-fifth annual meeting of the Central Society for Clinical Research, Chicago, Nov. 7, 1952.

Received for publication Nov. 8, 1952.

TABLE I. PREOPERATIVE STUDIES

PATIENT	AGE	SURFACE AREA SQ. M.	RV/TLV PER CENT	INDEX OF PULM. MIXING*	MBC L./M²	V.C. C.C./M²	OPERATION
H. P.	41	1.79	54.0	3.43	23.5	908	Pneumonectomy
R. D.	41	2.02	33.5	2.73	60.0	2611	Lobectomy
R. C.	26	1.88	21.5	2.78	57.7	2314	Lobectomy
J. V.	53	1.78	44.1	2.62	53.5	2346	Segmental resection
G. S.	29	1.75	31.3	4.21	43.2	2043	Segmental resection
E. O.	41	1.79	40.3	4.24	34.0	1872	Wedge resection
G. K.	34	1.82	49.2	2.58	43.6	1758	Lobectomy
T. G.	30	2.10	22.2	1.70	54.5	2762	Wedge resection
W. W.	22	2.04	15.8	3.53	35.5	1706	Segmental resection
D. S.	18	1.95	20.6	2.79	51.0	2641	Segmental resection
P. N.	27	1.79	16.7	2.03	67.6	2291	Segmental resection
S. M.	36	1.73	21.3	3.19	64.6	3121	Segmental resection
J. S.	53	1.58	48.0	3.93	41.0	1487	Segmental resection
Mean	34.7		32.2	3.06	48.4	2143	
S. D.			± 13.5	± .77	± 13.0	± 597	
Normal†			23.0	1.45	61.0	2290	
S. D.			± 4.1	± .23	± 6.0	± 274	

*Concentration of N_2 in alveolar air after breathing pure O_2 for seven minutes.
†Mean for sixteen normal men, 23 to 44 years of age.

The methods of study were essentially the same as those reported in the first paper in this series,[9] with certain modifications to make them applicable to the operating room. A polyethylene tube was inserted into the brachial artery through the lumen of a No. 15 gauge needle. The needle was then removed and the plastic tubing was flushed with heparin solution to prevent clotting. The indwelling plastic tube furnished a ready source of arterial blood without disturbing the patient, the surgeon, or the anesthesiologist.

The method for the measurement of the rate of carbon dioxide excretion was altered, since it was impossible to collect samples of expired air over a period of several minutes as was done in the previous studies. Instead, the expired gas was led through a 4 liter cylinder where it was mixed by a sparkless electric fan. Gas samples were drawn from this chamber for analysis of carbon dioxide concentration. The expired gas next passed through a volume displacement gas meter* and then passed back into the anesthesia machine circuit and through the soda lime chamber (Fig. 1).

Since alveolar ventilation has rarely been studied during surgery in human beings, it might be wise to mention the accuracy of the several measurements which contributed to its determination. These measurements were: (1) total ventilation, (2) carbon dioxide excretion, and (3) carbon dioxide concentration in the alveolar air.

A volume displacement gas meter of the type used in the home was employed for measurement of total ventilation. These meters are rated by the Minneapolis Gas Company and the manufacturer as having an accuracy within 0.5 per cent. The accuracy was checked frequently in this laboratory under the conditions of the present study and found to be within 1 per cent. For convenience the meter was equipped with a dial calibrated in liters rather than in cubic feet. The resistance of the meter is rated as being 1 cm. water

*Manufactured by the American Meter Co., Philadelphia, Pa., and supplied through the courtesy of the Minneapolis Gas Co.

at a gas flow of 71 L. per minute. This was checked and found to be less than 1 cm. water in the velocity ranges concerned (less than 60 L. per minute). In order to determine the effect of the resistance in practice, seven of the studies were done with the meter in the inspiratory arm of the anesthesia circuit, and six with it in the expiratory arm. No difference could be noted by the anesthesiologist. Furthermore, the pressure tracings that were taken when the meter was in the circuit showed no difference from those taken without the meter. There is one advantage in having the meter in the expiratory arm for if there should be a leak around the endotracheal tube cuff

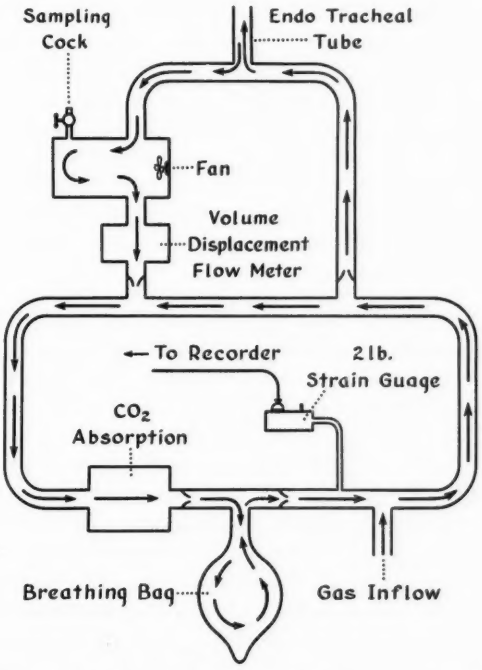

Fig. 1.—Diagram of the apparatus used for the measurement of total ventilation and rate of CO_2 excretion during surgery. It will be noted that the only gas which is expired by the subject passes through the gas meter and mixing chamber.

when positive pressure is applied, the gas which leaks out is not measured; therefore, the accuracy of the total ventilation measurement is assured. However, in these studies there was no apparent error with either method. Any leak around the endotracheal tube when the meter was in the inspiratory arm would give a falsely high total ventilation, and thus the calculated alveolar ventilation would also be falsely high. However, this did not occur in the patients so studied.

The measurement of the excretion of carbon dioxide depends upon two factors: (1) the measurement of total ventilation, which has been considered previously, and (2) the determination of the carbon dioxide concentration

within a representative sample of this gas. The latter was checked by collection and analysis of the expired air from normal subjects in a Tissot gasometer in the usual manner, after it had passed through the gas meter and the mixing chamber. The two methods gave results which checked within 2.0 per cent.

The concentration of the carbon dioxide in the alveolar air was calculated from the arterial blood P_{CO_2} and the prevailing barometric pressure. Alveolar P_{CO_2} was assumed to be equal to arterial blood P_{CO_2}. The latter was calculated from the pH, carbon dioxide content, hematocrit, and hemoglobin saturation of the arterial blood. Of these determinations only the method for the measurement of the pH need be mentioned in detail. This measurement was made on whole blood in a glass electrode, using a Cambridge potentiometer after the manner described by Wilson.[11] The electrode and all solutions were maintained at 38° C. in a constant temperature box, and the measurements were made within six minutes of the time the blood was drawn. The blood was collected in warmed syringes, in order to maintain the temperature at 38° C. The normal arterial blood pH has been found to be 7.40 ± .01 by this method. Since this is such a key determination for the study of alveolar ventilation, a great deal of attention was given to obtaining an accurate measurement for this study.

RESULTS

Before Anesthetization.—As an additional control, a blood sample was drawn for the determination of P_{CO_2} just before the induction of anesthesia. The mean value of 39.36 mm. Hg showed no change from the value of 40.22 mm. Hg done twenty-four hours previously (Fig. 2). No gas sample could be collected at this time for technical reasons, but it seems safe to assume that ventilation was essentially unchanged from the previous day.

Before Opening Chest.—Blood and gas were drawn for analysis about five minutes before the pleura was opened. This was about forty minutes after the induction of anesthesia and insertion of the endotracheal tube. At this time the mean pH had fallen to 7.32 and the P_{CO_2} had risen to 47.52 mm. Hg (Fig. 2). The total ventilation and alveolar ventilation were essentially unchanged from the control values of the previous day. This apparent discrepancy is probably explained by an accumulation of carbon dioxide during the insertion of the endotracheal tube. By the time the measurements were made the anesthesiologist had already begun to assist respiration, so that ventilation was improved. The carbon dioxide retention which had occurred during the insertion of the endotracheal tube had not been entirely corrected, however.

One-half Hour After Opening Chest.—At this time eleven of the thirteen patients showed a definite fall in the pH and rise in the P_{CO_2}. The mean pH was 7.21 and the mean P_{CO_2} was 69.16 mm. Hg. The mean total ventilation was 7.17 L. per minute, but the alveolar ventilation had fallen to 2.72 L. per minute. The control values were 6.50 L. per minute and 4.1 L. per minute, respectively.

From the time the pleura was opened the proportion of the total ventilation that participated effectively in alveolar ventilation showed a distinct drop from the values of the previous day and even from those obtained just before the chest was opened. Fig. 3 illustrates the relationship between the total ventilation, alveolar ventilation, and dead-space ventilation per minute in the thirteen cases. Sixty-one per cent of the total ventilation reached the alveoli on the day before surgery. Before opening the chest 54 per cent of the total ventilation was functionally effective (alveolar ventilation).. One-half hour after the opening of the thorax only 38 per cent reached functioning alveoli. This increased ventilation of dead space prevailed throughout the surgical period.

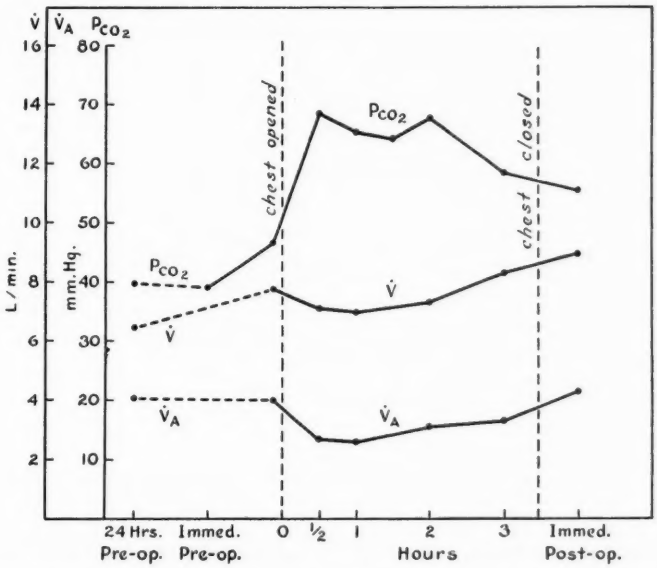

Fig. 2.—Mean values for P_{CO_2} total ventilation ($\dot{V}$), and alveolar ventilation ($\dot{V}_A$) before, during and immediately after thoracic surgery on thirteen subjects. The rise in P_{CO_2} was coincident with the fall in alveolar ventilation. Total ventilation was well maintained throughout.

Subsequent Determinations.—The deficiency of alveolar ventilation and elevation of P_{CO_2} persisted throughout the remainder of the surgical period. In several instances the anesthesiologist was told of the presence of an acidosis after one or two hours, and he made a conscious effort to improve ventilation and thereby increase the elimination of carbon dioxide. This was reflected in the data by the rise in the alveolar ventilation and fall in P_{CO_2} for the thirteen cases (Fig. 2).

Figs. 2 and 3 only include data for the first three hours after the opening of the chest, because several of the cases terminated before the four-hour sample could be obtained. However, two cases reached their peak P_{CO_2} after this three-hour period. The fact that not all patients reached their highest

P_{CO_2} at the same time accounts for the fact that the maximum changes shown in Fig. 6 do not correspond to the mean values for any single time as shown in Fig. 2.

Fig. 4 illustrates the ventilatory pattern and the P_{CO_2} of one patient (J. S.) who developed a significant acidosis. It will be noted that the P_{CO_2} line and the alveolar ventilation line are essentially mirror images. The total ventilation never fell below 5.6 L. per minute.

Fig. 5 illustrates the results in one of the two patients in whom ventilation was adequate during surgery. The P_{CO_2} remained below the control value throughout most of the operation.

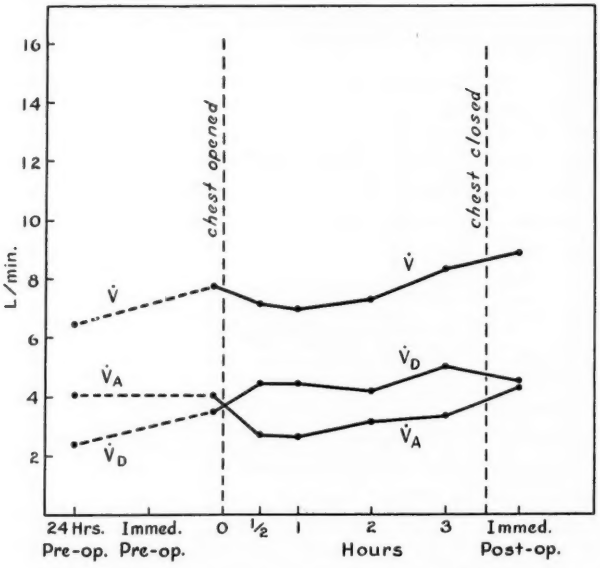

Fig. 3.—Relationship of the mean alveolar ventilation ($\dot{V}_A$) and dead-space ventilation ($\dot{V}_D$) to total ventilation ($\dot{V}$) before, during, and after thoracic surgery in thirteen subjects. The proportion of the total ventilation which reached only dead space rose slightly after anesthesia was induced and still further when the pleura was opened.

Fig. 6 presents the data from a slightly different point of view. The greatest change which occurred in the pH and P_{CO_2} at any time during the procedure is illustrated with the corresponding alveolar ventilation and total ventilation. The bars in Fig. 6 thus represent the mean preoperative values compared with the means for the extreme changes at the time when the P_{CO_2} was at its highest point. The actual values and the time of occurrence during the procedure are recorded in Table II.

The recording of the respiratory rate during the surgical procedure revealed that the rhythm of ventilation was irregular during surgery (Fig. 7). Long pauses often occurred while the anesthesiologist adjusted the intravenous infusion, administered blood, or suctioned the trachea. The rate of artificial respiration in this tracing was 18 per minute. In other cases the rate

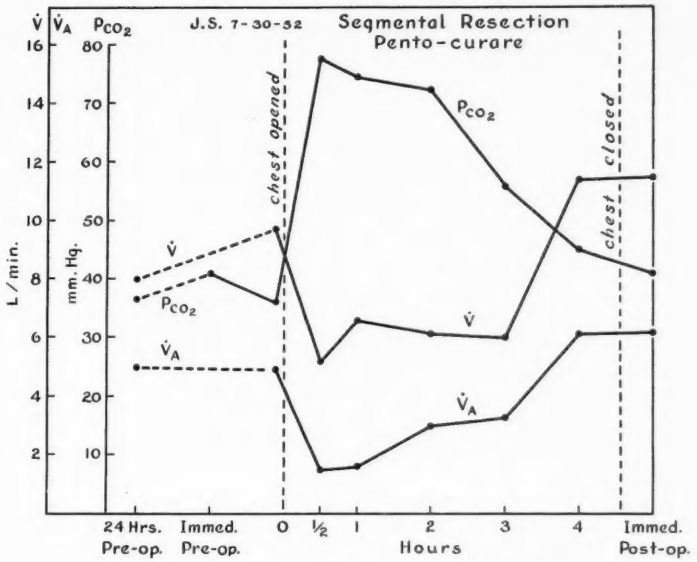

Fig. 4.—P_{CO_2}, total ventilation ($\dot{V}$), and alveolar ventilation ($\dot{V}_A$) in one of the patients who developed acidosis during surgery. The rise in the P_{CO_2} occurred coincident with the opening of the pleura and the fall in alveolar ventilation. The total ventilation was mildly lowered from the control values also.

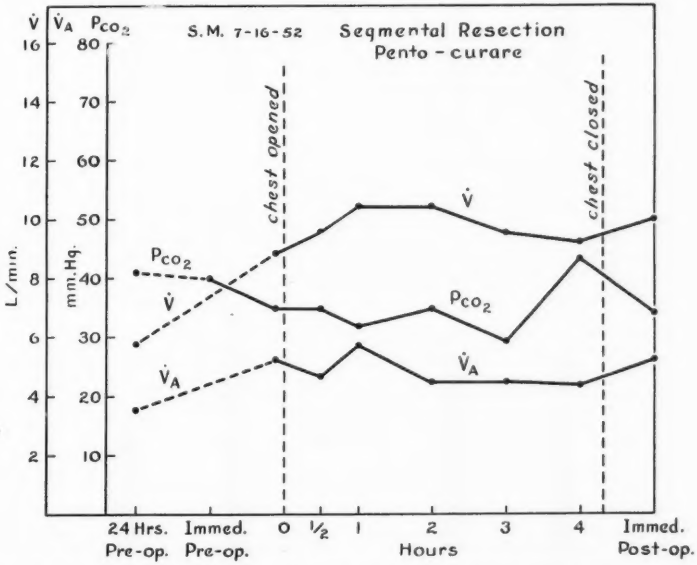

Fig. 5.—P_{CO_2}, total ventilation ($\dot{V}$), and alveolar ventilation ($\dot{V}_A$) of one patient who did not develop respiratory acidosis. The alveolar ventilation was maintained above control values throughout the period and the P_{CO_2} well below control values. The volume of total ventilation was greatly increased during surgery by the vigor of the manually assisted respiration.

TABLE II

PATIENTS	PREOPERATIVE pH	P_{CO_2}	$\dot{V}$	$\dot{V}_A$	AT TIME OF MAXIMUM P_{CO_2} pH	P_{CO_2}	$\dot{V}$	$\dot{V}_A$	TIME FOR OPENING CHEST	DURATION OF SURGERY
H. P.	7.41	45	5086	2861	7.07	110	7129	1284	1 Hr.	6 Hr.
R. D.	7.40	38	6935	4209	7.08	94	4668	1500	2 Hr.	5 Hr.
R. C.	7.40	43	5103	3454	7.05	110	4347	1077	2 Hr.	5 Hr.
J. V.	7.41	38	7755	4457	7.14	76	5048	1637	½ Hr.	3½ Hr.
G. S.	7.41	36	5574	4709	7.09	96	6081	1438	½ Hr.	3½ Hr.
E. O.	7.42	38	8945	4744	7.01	117	5544	850	½ Hr.	3½ Hr.
G. K.	7.40	41	7067	4551	7.21	70	—	—	After intubation	5½ Hr.
T. G.	7.43	38	7229	4639	7.30	52	7277	3378	1½ Hr.	2 Hr.
W. W.	7.40	42	6402	4138	7.10	105	9874	1347	6 Hr.	7 Hr.
D. S.	7.40	40	6425	4347	7.26	57	8743	4074	½ Hr.	3 Hr.
P. N.	7.39	43	4425	2544	7.21	67	4689	1686	1 Hr.	2½ Hr.
S. M.	7.40	41	5820	3657	7.32	44	9293	4394	3 Hr.	3 Hr.
J. S.	7.40	37	7945	4959	7.12	78	5601	1440	½ Hr.	3½ Hr.
Mean	7.405	40.0	6516	4098	7.155	82.0	6601	2143		
S. D.	± .013	± 2.74	± 1300	± 753	± .104	± 24.9	± 1920	± 1200		

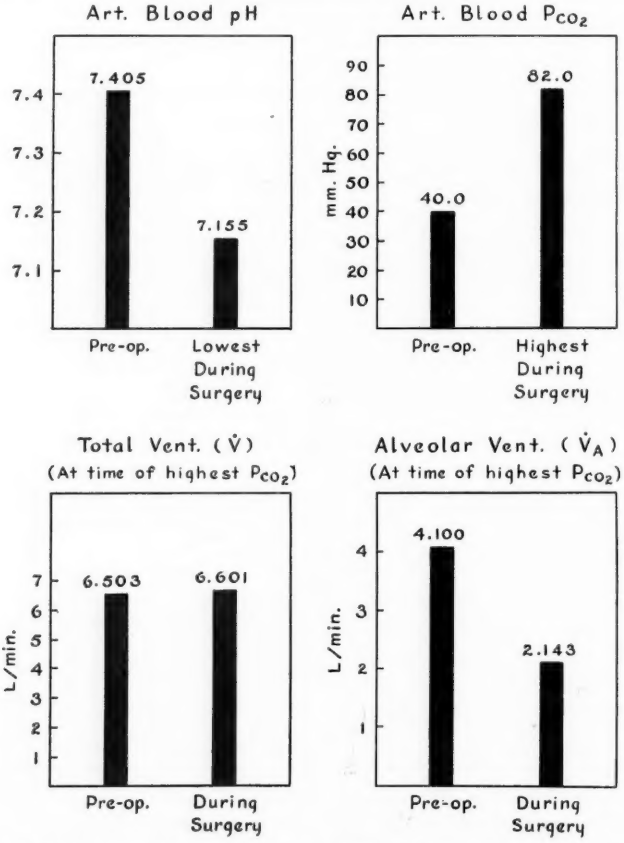

Fig. 6.—The mean maximum change in P_{CO_2} and pH which occurred at any time during the procedure in the thirteen subjects. The alveolar ventilation and total ventilation measurements which were made at the same times are charted below, showing a great fall in alveolar ventilation with a normal total ventilation. An increased ventilation of dead space accounts for this discrepancy.

often reached 30 per minute. The preoperative respiratory rates never exceeded 16 per minute. The patient's own respiratory efforts can be seen during the times when no artificial respiration was being given. The spontaneous rate in this instance was 19 per minute. The patient cannot be said to be apneic during the breaks in artificial respiration when there were spontaneous respiratory efforts. The segment of the tracing shown in Fig. 7 occurred over a twelve-minute period one hour after the chest was opened. Fig. 4 illustrates the P_{CO_2}, alveolar ventilation, and total ventilation at this time.

Fig. 7.—Recording of the respiratory pattern during surgery in J. S., whose data are illustrated in Fig. 4. Tracing was taken during a twelve-minute period one hour after the opening of the pleura. The P_{CO_2} was 80 mm. Hg at this time and the alveolar ventilation less than 2 L. per minute. The long pauses occurred while the anesthesiologist adjusted the blood transfusion, etc. Spontaneous respiratory efforts can be seen during the pauses.

DISCUSSION

The occurrence of an acidosis during anesthesia was first pointed out by van Slyke, Austin, and Cullen[12] in 1922, and was studied by Cullen and others[13] in 1923, and by Potter[14] in 1925. These authors pointed out that there was a rise in the P_{CO_2} and a fall in the alkali reserve within the first few minutes of anesthesia with ether and nitrous oxide. Potter postulated that phosphoric acid entered the blood and thus caused a metabolic acidosis. The occurrence of a distinct acidosis during ether anesthesia used in connection with

an open thoracotomy has recently been confirmed by several workers.[1-7] These workers found a definite fall in the whole blood buffer base and postulated a combination of respiratory and metabolic acidosis. Beecher and his co-workers[15] showed that ether was not at fault directly because acidosis did not develop when ventilation was adequate.

Dripps[16] pointed out that the drop in blood pressure often seen following cyclopropane anesthesia when the mask was removed was actually due to a rapid return of the P_{CO_2} from high levels toward normal. He showed that the retention of carbon dioxide could be prevented by better ventilation. This also prevented the postanesthesia fall in blood pressure. These results have been confirmed in dogs by Brown and others.[17-19]

Respiratory assistance has been used for several years during open chest operations, and in many major abdominal procedures, because of the known accumulation of carbon dioxide during anesthesia. Watrous, Davis, and Anderson[20] state that the object of controlled respiration is to maintain the P_{CO_2} below the threshold of the respiratory center so that the patient is apneic while the surgeon is working. The ventilation is maintained by intermittent positive pressure artificial respiration when the surgeon turns from the field. Watrous states that by such means the anesthesiologist is able to maintain the patient in a near normal physiologic state.

Maloney, Derrick, and Whittenberger[21] found that in their experience such manually assisted and controlled respiration failed to achieve ideal results. They described the patients as restless and stated that it was difficult to prevent troublesome diaphragmatic motion without excessive anesthetization. The patient became more relaxed with the same dose of anesthetic when ventilation was increased by the use of a mechanical respiration assistor. Furthermore, the mediastinum became quiet which facilitated the surgeons' work. They calculated the alveolar ventilation from the measured ventilation volume and a constant dead-space volume, but did not actually measure the alveolar ventilation or the P_{CO_2} in their patients. Several other devices have been described which furnish mechanically controlled artificial ventilation in an attempt to improve ventilation during anesthesia.[22-25]

Unfortunately, few of the reports include acid-base data. Only one report was found in which alveolar ventilation was studied during surgery.[27] Von Bühlmann and Hotz reported a close relation between the alveolar ventilation and the blood pH during thoracic surgery. They felt that the acidosis was due purely to a retention of carbon dioxide because of inadequate alveolar ventilation, and that acidosis could be prevented by more vigorous ventilation.

The present study shows that it is the amount of air reaching the alveoli which determines the acid-base balance during surgery. The P_{CO_2} of the arterial blood remaining within normal limits when the alveolar ventilation was maintained at the preoperative level. When alveolar ventilation fell, the P_{CO_2} rose proportionately. There was no correlation between the total ventilation and the level of the P_{CO_2} ($r = .094$). The P_{CO_2} frequently rose to levels in excess of 100 mm. Hg while the total ventilation was as great as the control values. This discrepancy probably arose from an increased ventilation of dead

space during the controlled respiration. There are two possible explanations of this phenomenon. First, the respiratory rate may be increased so that with a constant dead space the minute volume of dead-space ventilation would be increased. This seems to have been a determining factor in our patients, since the preoperative respiratory rates varied between 10 and 16 per minute and the rates during anesthesia often exceeded 24 per minute. Second, the actual volume of dead space of the respiratory tree may be increased. This seems possible, because it is likely that the operated lung is poorly perfused during the time the chest is open. Both of these factors probably played a part, because the increase in dead space seemed to occur in two steps: (1) at the time of anesthetization when the respiratory rate was controlled by the anesthesiologist, and (2) at the time the chest was opened and one lung was functioning below par.

The change in the pH, CO_2 and P_{CO_2} which occurred in most of our patients closely simulated the results reported by Whitehead and others[26] on dogs during diffusion respiration with pure oxygen. In their studies the pH of arterial blood fell rapidly while the arterial oxygen concentration remained high. The changes observed by Whitehead occurred more rapidly, but their dogs had no ventilation at all. The changes demonstrated in the patients in this series occurred more gradually because the patients did have some respiratory exchange.

It cannot be denied that the artificial respiration of the patients in this series did not conform to the definition of controlled respiration. Controlled respiration is defined as being sufficient to keep the patient apneic.[20] From the tracing in Fig. 7 it is clear that this was not true in these cases. During periods when no artificial respiration was being given there were definite spontaneous respiratory efforts on the part of the patient. In the two patients who were maintained in a normal state for a large part of the surgical period, there was true apnea during the pauses. The volume of gas which the patient obtained by spontaneous effort was about 100 c.c. during the time the chest was open. Such respiratory efforts were too slight to be readily noticed by the anesthesiologist. As a result, he thought that he was practicing controlled respiration. To our knowledge no such records have been taken during surgery, so that the only criterion used by anesthesiologists has been the ability to detect respiratory efforts. In this sense, these cases do fit the definition of controlled respiration.

The anesthesiologists who administered the anesthetic and the controlled respiration were members of the regular anesthesiology staff, or were residents in training. It was not felt that the inadequacy of alveolar ventilation which was observed was due to poor work on their part. It seemed to be a part of a larger problem, the lack of reliable signs to guide the control of respiration during anesthesia. Reports of more severe acidosis than observed in this series have come from various parts of the country, indeed from every hospital where such studies have been undertaken.[1-7]

It is not the purpose of this paper to condemn controlled respiration technique in anesthesia, but merely to point out that, as commonly used, it

accomplishes an inadequate alveolar ventilation. The case of S. M. illustrated in Fig. 5 shows that this situation need not occur. In this patient the alveolar ventilation was maintained at or above the control value throughout the period of anesthesia. The P_{CO_2} remained normal. There were only two patients in the thirteen studied who had an adequate alveolar ventilation during the anesthesia. It should be noted that those patients were relatively young men with good pulmonary function, and the amount of the anesthesiologist's time required for blood replacement and other procedures was minimal. Furthermore, they were among the later studies and the anesthesiologists were aware of the findings in the earlier cases. Because of this they made a particular effort to maintain adequate ventilation. Therefore, these cases are not representative of the problem as it occurs every day.

SUMMARY AND CONCLUSIONS

1. P_{CO_2}, total ventilation, and alveolar ventilation were determined before and throughout the period of anesthesia in thirteen patients who underwent major thoracic surgical procedures.

2. There was no correlation between the total ventilation and the P_{CO_2} ($r = .094$). The picture of the acidosis which occurs during anesthesia cannot yet be considered complete, because adequate blood studies of the fixed acids have not been reported. However, the major factor would appear to be the inadequacy of alveolar ventilation during the period of anesthesia.

3. The pattern of the artificial respiration given by the anesthesiologist was found to be irregular. There were significant pauses (up to 80 seconds) when no ventilation was given. These pauses were due to the necessity of the anesthesiologist to adjust the intravenous infusion, to administer blood, and frequently to suction mucus from the trachea.

The authors are indebted to Shirley Lundgren and John Oganovich for technical assistance.

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PERSONAL EXPERIENCES WITH TEN CONSECUTIVE CASES OF HEART WOUND TREATED SUCCESSFULLY BY PERICARDIOTOMY AND CARDIORRHAPHY

With Reference to Seventy-Four Earlier Cases, Fifty-Four Surgically Treated at Harlem Hospital

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IT IS the purpose of this paper to present studies of ten consecutive cases of injuries to the heart which were treated successfully by pericardiotomy and cardiorrhaphy and to discuss briefly the salient features of seventy-four earlier cases which were admitted to Harlem Hospital within the past fifteen years. In addition, the significant findings in necropsy protocols of the twenty cases that died before surgery could be instituted are enumerated.

GENERAL CONSIDERATIONS

In ten consecutive cases treated by thoracotomy the clinical signs of acute cardiac tamponade were observed: three of these were in extremis, moribund, with a blood pressure of 0/0 and nonperceptible pulse; five were in profound shock with a blood pressure of 0/0, with a pulse which was barely perceptible; the other three patients were in mild to moderate shock. In five of these cases the wounds were intraluminal (into cardiac chambers). In three cases there was incomplete laceration of the myocardium, and in two, lacerations of the pericardium alone were found.

These cases, all successfully treated, clearly indicate that unless surgery is instituted, the definition of the exact pathology involved is unknown. In dealing with injuries of the heart, there is no way of determining whether the site of injury is in the auricles, ventricles, intrapericardial or extrapericardial portion of the great vessels, pericardium alone, internal mammary or intercostal vessels unless the patient is subjected to exploratory thoracotomy.

These ten cases were supervised in the operative field by one of us (E. A. N.) and were operated upon by the residents in surgery, some of whom had had less than three months' training in thoracic surgery. These excellent results are attributable to a routine of management which has evolved over a period of fifteen years of experience in the treatment of cardiac injuries at Harlem Hospital.[1]

Death in heart wound cases is due to exsanguination and cardiac tamponade. In the twenty cases that did not survive long enough for immediate surgery, necropsy revealed exsanguination in thirteen. In three cases death was attributed to tamponade. In the remaining four cases, death was due to severe hemorrhage from other sources. (See Table I.)

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Read (by title) before the Thirty-second Annual Meeting of The American Association for Thoracic Surgery at Dallas, Texas, May 8-10, 1952.

TABLE I. SALIENT NECROPSY FINDINGS IN TWENTY PATIENTS DYING BEFORE SURGERY

CAUSES		NO. OF CASES
Exsanguination from cardiac wounds (Without sufficient tamponade to control hemorrhage)		13
Exsanguination from associated injury (With varying degrees of tamponade)		4
Internal jugular vein	1	
Femoral vessels	1	
Abdominal viscera (Liver, spleen, inferior vena cava)	2	
Tamponade (With minimal loss of blood)		3
Total		20

Among the patients who survived long enough for exploration to be performed surgically, there was evidence of cardiac tamponade. In some cases there was no evidence of any pleural involvement, and in others there were varying degrees of hemothorax. Tamponade of the heart allows the patient to survive because it contributes to the reduction or cessation of hemorrhage from the cardiac wound, but in addition it will produce a profound shock which may prove fatal unless relieved. In all heart injuries, pericardium included, the clinical picture common to all is shock.

DIAGNOSTIC CRITERIA

The clinical picture of injury to the heart has been described frequently. The diagnosis is relatively easy if the condition is remembered in every chest wound case and if it is suspected in all patients with stab wounds over or near the precordium. It has been our experience at Harlem Hospital that external wounds in the axillary region, posterior chest wall, base of the neck, and upper abdomen may also be associated with a cardiac wound. There may be a brief period of freedom from symptoms, during which time the patient may even walk a short distance; this will be followed by rapid collapse. The heart sounds are distant or feeble. The blood pressure is falling or absent. In approximately 10 per cent of the cases there is evidence of turgescence of the neck veins. Respirations are rapid, sighing in type, and the excursions are usually irregular. In addition, there may be symptoms and signs resulting from an associated laceration of lung, tension pneumothorax, and a progressive hemothorax; all add to the picture of shock.

Venous pressure readings, electrocardiographic studies and x-ray pictures, including fluoroscopy, may be helpful but are not to be depended upon in establishing a diagnosis. The x-ray film demonstrates a widening of the cardiac silhouette in some cases. Also in some cases fluoroscopy reveals a diminution of cardiac pulsations. These commonly used studies may be of no value since death may occur from an amount of blood in the pericardial sac too small to cause any noticeable changes in the pulsations, and size and contour of the cardiac shadow. Restlessness of the patient also makes these studies difficult. X-ray studies, including fluoroscopy, are of importance when they demonstrate a hemothorax or hemopneumothorax in the presence of symptoms and signs of heart injury. This indicates that bleeding is occurring into the pleural space. Incidentally, in this situation venous pressure readings though pathognomonic when increased may be normal, or even lower than

TABLE II. SALIENT FEATURES OF TEN CONSECUTIVE HEART WOUND

CASE NO.	INITIALS, AGE, AND SEX	TIME BETWEEN INJURY & SURGERY	SITE OF LESION	ADMITTING BLOOD PRESSURE	WEAPON	PREOPERATIVE X-RAYS	TAMPONADE	ASSO PATH
1	E. S. 25 F	6 hr.	Pulmonary conus (intraluminal?)	0/0	Knife	Clear lung fields; widening of cardiac shadow (?)	Positive large clot 15 c.c. of fluid blood	None
2	W. W. 30 M	2 hr., 20 min.	Right ventricle (intraluminal)	0/0	Knife	Left hemothorax & widening of heart shadow	Positive 100 c.c. of blood & clot	Left he
3	G. P. 21 M	1 hr., 30 min.	Right auricle (intraluminal)	0/0	Ice pick	Clear lung fields; widening of heart shadow	Positive 75 c.c. of blood. No clot	None
4	V. T. 26 M	2 hr., 40 min.	Left ventricle (incomplete laceration of myocardium)	0/0	Knife	Left hemothorax; moderate widening of heart shadow	Positive	Left he
5	A. J. 34 F	2 hr.	Right ventricle (intraluminal)	0/0	Knife	Cardiac contour increased with evidence of pulmonary congestion in both lung fields	Positive 200 c.c. fluid blood with many clots	Evidenc gesti lung coton
6	C. K. 31 M	3 hr., 30 min.	Left ventricle (incomplete laceration)	0/0	Knife	Negative	Positive 500 c.c. blood & clots	None
7	L. P. 28 M	3 hr., 30 min.	Right ventricle (incomplete laceration)	50/0	Ice pick	Enlarged heart shadow; lung fields clear	Positive fluid blood under tension. No clots	None
8	L. R. 24 M	8 hr.	Pericardium alone	96/60	Knife	Left hemothorax	Positive pericardial laceration myocardium intact	None
9	J. T. 54 M	1 hr., 45 min.	Pericardium alone	40/0	Knife	Marked interstitial emphysema-mediastinum	None. Pericardium only	Periphe lacer

WOUND CASES TREATED BY PERICARDIOTOMY AND CARDIORRHAPHY

ASSOCIATED PATHOLOGY	REPAIR OF WOUND	POSTOPERATIVE COURSE	COMMENT
None	Not sutured	Sinus tract in wound; healed in 16 days	Tapping would have been unsuccessful in this case because of the large clot present weighing 50 grains and measuring 7.5 cm. by 5 cm. by 5 cm., and absence of significant amount of fluid blood in pericardial sac
Left hemothorax	Interrupted 00 Deknatel	Uncomplicated	Due to overenthusiasm of the operating resident, patient almost exsanguinated, since the pericardium was opened before the scrub nurse had finished preparing the initial heart suture. Therefore, it is mandatory that the operating surgeon check with the suture nurse before incising the pericardium since at this point in the operation, excessive bleeding usually occurs, and the use of a suture for traction or closure may be lifesaving
None	Interrupted 00 Deknatel	Atelectasis, right middle & left upper lobe	Auricular wounds are usually fatal because of the thinness and friability of the tissue, allowing excessive bleeding. Digital compression for the control of hemorrhage, commonly used in ventricular wounds, is not effective over the auricles. In this case, the edges of the wound were grasped with Allis clamps which were crisscrossed for control of hemorrhage while sutures were placed and tied with utmost gentleness
Left hemothorax	Single figure of 8 suture	Uncomplicated	Though this was not a wound penetrating into the chamber, bleeding was extremely active at the time of systole, during repair, and this patient in all probability could not have been treated by aspiration alone in view of the progressive left hemothorax
Evidence of congestion of left lung on thoracotomy	Interrupted 000 Deknatel	Uncomplicated	An essential feature in technique is to present the site of laceration for suturing. With our routine left fourth intercostal transpleural approach with transection of adjacent cartilages, any part of the heart may be made accessible for suturing. In this case, the wound was retrosternal but easily brought into view by traction on the mesial edge of the pericardiotomy incision
None	Interrupted 0 Deknatel	Uncomplicated	In spite of negative x-rays, there was a large amount of blood and clot in the pericardial sac causing tamponade. This demonstrates the fallibility of x-rays for diagnosis in some cases
None	Not sutured	Uncomplicated	Preoperative aspiration of pericardium in this case yielded only five c.c. of serous fluid. At operation soon afterward, fluid blood was found. This case probably would have done just as well with pericardial aspiration inasmuch as the lung fields were clear, the cardiac shadow was widened and the pericardium contained only fluid blood. At operation there was nicking of the right ventricle. This did not require any suturing. This case represents a failure of an attempt at aspiration
None	None	Uncomplicated	In this case all evidence pointed to an injury of the heart preoperatively. At operation, blood spurted from a branch of the pericardiophrenic artery in the pericardium. Bleeding occurred principally into the left pleural space, although it occurred into the pericardial sac as well, in amount not large enough to have significant tamponade
Peripheral lung laceration	None	Uncomplicated	The history, physical examination and diagnostic work-up suggested a wound of the heart. At operation there was an incised wound of the pericardium only with associated lung laceration

TABLE I (CONT'D)

10	L. S. 40 M	1 hr., 50 min.	Left ventricle (intra-luminal)	0/0	Knife	No preoperative x-rays taken	Positive fluid, blood & clot

normal, without significant enlargement of the cardiac shadow. In these cases thoracotomy is mandatory for the control of bleeding whether it is cardiac in origin or from other sources.

When history and physical findings are suggestive of heart injury, our decision is forthright—exploratory thoracotomy. Over the time span of this series only six cases were explored for cardiac injury of the intercostal or internal mammary artery or for laceration of lung tissue.

ASPIRATION OF PERICARDIAL SAC

Aspiration of blood from the pericardial sac, as a specific therapeutic measure or to prepare the patient for surgery, may be valuable and effective in the management of cardiac tamponade in certain instances. In cases where the x-ray films demonstrate clear pulmonary fields in the presence of signs and symptoms referable to heart tamponade, aspiration of the pericardial sac should be done. A patient in extremis with cardiac tamponade may be given sufficient relief with aspiration of blood from the pericardial sac to allow time to prepare for pericardiotomy. However, we are opposed to the routine use of pericardial aspiration for the following reasons:

1. Recently, of three patients in whom pericardial aspiration was done in the operating room, one patient died before surgery could be instituted; in another aspiration yielded nothing, and at operation immediately following tapping numerous large clots were encountered. In the third case, 5 c.c. of serous fluid was obtained without any significant improvement in the condition of the patient, and immediately following the tap, thoracotomy revealed frank blood in the pericardial sac (see Case 7). In addition, the reversibility of shock at the time of aspiration is unknown, and any further delay may prove fatal.

2. In approximately 50 per cent of the cases, large formations of clot were found in the pericardial sac.

3. It has been shown[2] that in the ventricles, after cessation of hemorrhage without suture, usually a thrombus remains and organizes. This results in the formation of a relatively thin cicatrix in the region of the epicardial opening. The remaining part of the wound tract, instead of healing, may persist as an open space connected with the heart chambers and lined by endothelium. Thus, a false sacculated cardiac aneurysm may result.

4. The technique of aspiration, as usually done with the patient in a supine position, while simple, may be hazardous because of danger of injury to coronary vessels or to the myocardium. This danger is increased in tamponade because the heart is pushed forward by the blood accumulating in the posterolateral pouches and posteriorly in the oblique sinus (cul-de-sac of Haller) or left atrial bursa. Because of this anatomic feature, and clot forma-

ft hemothorax	Two figure of 8 Deknatel	Uncomplicated	This case was sent immediately to the operating room. We have found that history and physical are sufficient for diagnosis in these cases. Other diagnostic procedures while frequently done are time consuming and may be deleterious in the desperately ill patient

tions, removal of all blood elements becomes exceedingly difficult. This predisposes to an adhesive or constrictive pericarditis.

5. Exploratory thoracotomy carries with it a minimum of risk even in these critically ill patients as evidenced by the success in this series of cases.

For these reasons operative treatment has been preferred.

The details of operative technique used at Harlem Hospital in the treatment of cardiac wounds have been described previously.[1, 3] Nevertheless, it should be mentioned that in spite of the urgency of exploration, a deliberate systematized routine, that is, operating speedily but not hastily, and observing meticulously the principles of surgical technique, must be followed.

The pericardial sac is always left widely open. The postoperative management is similar to that of any transpleural procedure. The necessary period of hospitalization varies with the severity of the injury to the myocardium, complications and other associated injuries.

CASE PRESENTATIONS

The pertinent features of the ten consecutive cases are presented in Table II.

SUMMARY AND CONCLUSIONS

1. Personal experiences with ten consecutive cases of heart wounds treated successfully by pericardiotomy and cardiorrhaphy are presented.

2. Death in cardiac wounds is due to exsanguination and cardiac tamponade. More often in the patients who die before treatment can be instituted, the cause is exsanguination.

3. Cardiac tamponade prevents death from hemorrhage, but may prove fatal unless relieved by aspiration or pericardiotomy.

4. A diagnosis of heart injury should be made principally on the basis of history and physical examination, rather than depending upon roentgenographic studies, venous pressure readings, or electrocardiographic tracings, though all these may be useful adjuncts in establishing the diagnosis.

5. Aspiration of blood from the pericardial sac, as a specific therapeutic measure or for preparing the patient for surgery, may be valuable and effective in the management of cardiac tamponade in certain cases.

6. The reasons for recommending surgery in preference to aspiration as a routine procedure in this institution have been enumerated.

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THORACOPLASTY AND RESECTION FOR PULMONARY TUBERCULOSIS

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THIS is a report of the results of the surgical treatment of 235 patients at Kennedy Veterans Hospital between Jan. 1, 1947, and Oct. 1, 1951. There were 111 consecutive patients treated by the Alexander type thoracoplasty.[1] Seven of these patients, in addition to 124 others, are the total number of patients who have had a resection of a tuberculous pulmonary lesion between these dates.

The follow-up data were obtained between Dec. 1, 1951, and April 1, 1952, by the Thoracic and the Pulmonary Disease Section of Kennedy Hospital, by Veterans Administration Hospital No. 88 in Memphis, by communication with other Veterans Administration hospitals, physicians, local county or state health departments, and the patients. The status of the patients having a resection has been frequently checked and reported at the streptomycin or chemotherapy conferences of the Army, Navy, and Veterans Administration.[2, 3] The follow-up of patients treated by thoracoplasty is not complete as it has not been possible to locate eleven patients.

The age incidence is given in Table I. Eighty-two per cent of the patients who had resection and sixty-eight per cent of the patients who had thoracoplasty were between 20 and 40 years of age. There were only two women in both groups.

The extent and type of the lesions, according to the classification of Rubin and Klopstock,[4] is indicated by Table II. Ninety-six per cent of the thoracoplasty group and seventy-nine per cent of the resection group had nonprogressive cavitary fibrocaseous disease. Only two of the thoracoplasty group and twenty of the resection group had progressive caseocavernous disease.

Ideally, a follow-up study of patients with pulmonary tuberculosis would show their status at yearly intervals after operation and after the onset of illness until the death of all patients. However, this will be rarely, if ever, possible. It is difficult to determine accurately the yearly rate of progression, relapse, and death even in large series of cases followed for a varying number of years. The sum of the number of months of observation of all patients operated upon in a given year divided by 12 is shown graphically in Fig. 1. It may be noted that only eight patient years of observation of those treated by thoracoplasty are derived from the 1951 patients. Polack and Fidler[5] found that although the majority of patients did not have negative sputum cultures immediately following the completion of thoracoplasty 75 per cent were converted

From the Thoracic Surgery Section, Veterans Administration Medical Teaching Group, Kennedy Hospital.

Read (by title) before the Thirty-second Annual Meeting of The American Association for Thoracic Surgery at Dallas, Texas, May 8-10, 1952.

TABLE I. AGE INCIDENCE

AGE	THORACOPLASTY	RESECTION
20-30	33	38
31-40	43	69
41-50	15	15
Over 50	20	9
Total	111	131

after six months, 86 per cent after seven months, and 96 per cent by the end of a year. We believe that the success or failure of any form of treatment of most cases of pulmonary tuberculosis is obvious within a few months if everything bearing upon the case, as suggested by Alexander,[6] is known.

It may be noted also that 224 patient years of observation of the patients having a pulmonary resection are derived from over one year of observation.

TABLE II. EXTENT AND TYPE OF DISEASE

	THORACOPLASTY				RESECTION			
		CONTRALATERAL DISEASE				CONTRALATERAL DISEASE		
TYPE DISEASE	NO.	NONE	INACTIVE	ACTIVE	NO.	NONE	INACTIVE	ACTIVE
Fibrocaseous	107	74	32	1	104	69	33	2
Fibroid	2	2	0	0	7	7	0	0
Caseocavernous	2	0	1	1	20	13	4	3
Total	111	76	33	2	131	89	37	5

All of these cases have been treated during the streptomycin era, although not all of the patients having a thoracoplasty were given the antibiotic as is true of the cases having a lesion resected.

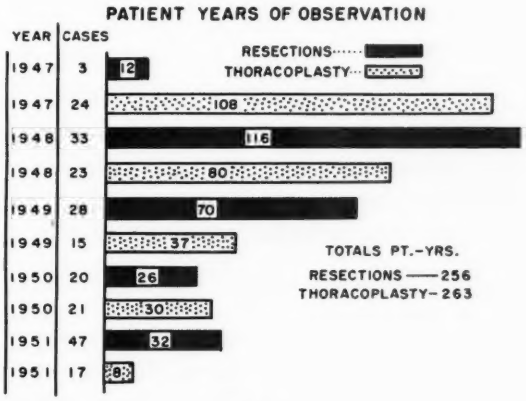

Fig. 1.

An analysis of fatality is given in Tables III and IV. There were two operative deaths in each group giving a sixty-day mortality rate of 1.5 per cent for resection and 1.8 per cent for thoracoplasty. There were 251 thoracoplasty stages performed with a mortality of 0.8 per cent per stage. Progressive pulmonary tuberculosis caused fifteen per cent of the total of twenty-one deaths. Two deaths were due to cancer, in the presence of quiescent or inactive

TABLE III. ANALYSIS OF FATALITIES
THORACOPLASTY

	P.O. DAY	NO.
Postoperative (111 patients; 251 operations)		
Progressive bilateral disease	33	1
Transfusion reaction, shock, hemorrhage	1	1
Operative total: 2 1.8% per patient 0.8% per stage		
	MONTHS	NO.
Late deaths		
Progressive pulmonary disease	4 to 42	7
Tuberculous meningitis	4	1
Carcinoma lung (1); Larynx (1)	10 to 18	2
Total late deaths: 10 (9.0%)		
All deaths: 12 (10.8%)		

pulmonary tuberculosis; one death was due to shock, hemorrhage, and transfusion reaction; one occurred in a chronic alcoholic with inactive disease; and another occurred in a dope addict with apparently cured tuberculosis. The remaining death was due to tuberculous meningitis.

TABLE IV. ANALYSIS OF FATALITIES
RESECTION

	P.O. DAY	NO.	
Postoperative (60 days)			
Progressive disease	10 to 46	2	1.5%
	MONTHS	NO.	
Late deaths			
Progressive pulmonary disease	4 to 26	5	
Nontuberculous	22 to 24	2	
Total late deaths: 7 (5.3%)			
All deaths after resection: 9 (6.9%)			

The twelve deaths during 263 patient years of observation give a fatality rate of 4.6 patients per 100 patient years for the thoracoplasty group. Lees and his co-workers[7] followed 278 patients from five to fifteen years after thoracoplasty and found that 75, or 27 per cent, were dead, at least 2 deaths per 100 patient years of observation. Of our patients 9, who had a resection, died during 256 patient years of observation, a fatality rate of 3.5 patients per 100 patient years. Long periods of follow-up of thoracoplasty cases have been reported by Adie,[8] Dolley,[9] Gutheil,[11] Kinsella,[12] Ottosen,[14] Skinner,[15] and their respective co-workers, Douglas,[10, 12] Shaw and Paulson,[13] and Rubin and Klopstock.[4] Based on the number of deaths and an estimate of the number of 100 patient years of observation there was a death rate of 2 to 3 patients for each 100 patient years of observation. Theoretically, a later follow-up of our cases may show a lower rate of deaths inasmuch as the patients with progressive disease may have already succumbed. Before streptomycin was available, it is well known that "better-risk" patients were selected for surgery. Neither chemotherapy nor other treatment has changed the progressive nature of pulmonary tuberculosis in some of our patients.

Overholt, Wilson, and Gehrig[16] reported the deaths of 71 patients following resection in 220 patients prior to streptomycin. They also reported the deaths

of 16 patients among a group of 208 patients following resection who were treated with streptomycin. However, when the approximate 1,000 patient years of observation of the prestreptomycin group is compared with the approximate 333 patient years of the streptomycin group, the fatality rate of 7 per 100 patient years compares less unfavorably with the fatality rate of 5 per 100 patient years of the streptomycin group.

The postoperative complications for the thoracoplasty group are given in Table V. A spread of the disease was noted in ten patients, six in the contralateral lung and four in the ipsilateral lung. The great value of antibiotics for these patients is well known.

TABLE V. THORACOPLASTY POSTOPERATIVE COMPLICATIONS

COMPLICATIONS	NO.	
Wound infection	1	
Postoperative spreads		
Contralateral	6	
Ipsilateral	4	
Total	10	9% per pt. 4% per stage
Miscellaneous		
Pleural tears	3	
Pleural effusion	3	
Hemothorax	1	
Phlebitis	1	
Jaundice	1	
Horner syndrome	2	
Atelectasis	3	
Epididymitis	1	

Table VI gives the operative complications and mortality following pulmonary resection. Spread of the disease occurred in ten of these patients also, but only three spreads occurred during the period that streptomycin and PAS were given. Important factors in preventing spreads were selection of the time for surgery in regard to stability of the lesion, tubercle bacilli sensitive to antibiotics, care in the positioning of the patient during operation, and constant aid in the removal of secretions both during the operation and later.

Two patients developed clotted hemothoraces after resection that responded to evacuation and partial thoracoplasty. Two patients developed small hematomas at the site of the pulmonary excision that absorbed during subsequent observation. Soon after these complications occurred, we discontinued the use of Foley catheters and returned to the use of two No. 32 French rubber tubes with multiple perforations.

Four chest wall sinuses have been present in patients who had a pneumonectomy. Three of these occurred in patients who had bacilli resistant to streptomycin. One patient has a recurrent tuberculous chest wall infection following lobectomy and subsequent modified thoracoplasty.

Fistulas have not been as troublesome since better technique has been used in doing segmental resections and in closing the bronchial stump. We avoid leaving denuded cartilage and obtain good contact of the pleural flap with the bronchial stump.

TABLE VI. OPERATIVE MORTALITY AND COMPLICATIONS

PROPHYLAXIS	PTS.	OP.	DEATHS	SPREAD	FISTULA	EMPYEMA	WOUND INF.	OTHER
Streptomycin	65	68	1 (1.5%)	7 (10.3%)	9 (13.2%)	9 (13.2%)	6 (8.8%)	4
Intermittent streptomycin and daily PAS	66	67	1 (1.5%)	3 (4.5%)	1 (1.5%)	2 (3%)	2 (3%)	6
Total	131	135	2 (1.5%)	10 (7.4%)	10 (7.4%)	11 (8.1%)	8 (5.9%)	10 (7.4%)

TABLE VII. PRESENT STATUS OF PATIENTS WITH A LATE SPREAD

				PRESENT STATUS								
				INACTIVE PER CENT			ACTIVE PER CENT			DEAD PER CENT		
OPERATION	CASES	SPREADS NO.	SPREADS %	NO.	PT.	SPREADS	NO.	PT.	SPREADS	NO.	PT.	SPREADS
Thoracoplasty	111	31	29.3	12	10.8	39	12	10.8	39	7	6.3	22
Resection	131	24	18.0	13	9.9	54	6	4.6	25	5	3.8	21

The incidence of empyema has decreased with a decrease in the incidence of fistulas. The pathogenesis of fistulas has been presented by Stemmermann, Daniels, and Averback.[17] Since late fistulas may result from empyema this is an added reason for prompt treatment or prevention of empyema. Following pneumonectomy, we prefer to keep the pleural space relatively dry and usually perform an early thoracoplasty.

The tendency of tuberculous lesions to spread is well known. Mitchell[18] found that 37 per cent of patients with minimal lesions had a spread of the disease over a period of five years after leaving the sanatorium. Bobrowitz[19] found that 42 per cent of minimal cases had a spread over a period of five years. It is estimated that 6 to 8 per cent of patients in sanatoriums on bed rest have a spread of the disease each year. Canada and his associates[20] report that in a group of 202 patients with acute stationary or progressive disease treated 120 days with 1.8 or 2 Gm. of streptomycin, 24 per cent relapsed by the end of the first four months following cessation of therapy. The fatality rate was 28 per cent for three years or nine patients per 100 patient years of observation.

The number of late spreads is given in Table VII. Spreads occurred in thirty-one patients who had a thoracoplasty (29.3 per cent) and in 24 patients who had a resection (18 per cent). Thus the late spread rate in terms of 100 patient years is 11 for thoracoplasty and 7 for resection. About one-fifth of the patients in both groups subsequently died. The percentage of patients with a spread following a resection that have since become inactive (fifty-four per cent) is greater than the percentage inactive who had a late spread following thoracoplasty (39 per cent). The number of patients with spreads continuing to have active disease at present is also less in the patients treated by resection.

TABLE VIII. RESULTS ACCORDING TO TYPE OF DISEASE AFTER THORACOPLASTY

TYPE OF DISEASE	NO.	INACTIVE	ACTIVE	DEAD	UNKNOWN
Fibrocaseous	107	69	17	10	11
Fibroid	2	2	0	0	0
Caseocavernous	2	0	0	2	0
Total	111	71 (64%)	17 (15%)	12 (11%)	11 (10%)

The late results for the thoracoplasty group are given in Table VIII and for the resection group in Table IX. The inactive group includes those patients who feel well, whose roentgenogram does not show active disease, and those who have negative sputum. Sputum cultures have been obtained whenever possible. The results in these tables must be considered in the light of the short period of observation. Even so, 79 per cent well, following resection, is considerably better than 64 per cent obtained by thoracoplasty.

TABLE IX. RESULTS ACCORDING TO TYPE OF DISEASE AFTER RESECTION

TYPE OF DISEASE	NO.	INACTIVE	ACTIVE	DEAD
Fibrocaseous	104	90 (86%)	12	2
Fibroid	7	5 (71%)	1	1 (Non-TBC)
Caseocavernous	20	8 (40%)	6	6
Total	131	103 (79%)	19 (14%)	9 (7%)

Resection of the lesion has subsequently been done for ten of the patients treated by thoracoplasty. Seven of these resections were done at Kennedy and are also included in the resection group. Three were done elsewhere. The sputum of all ten patients is now negative. Two patients were offered resection which they refused and both have subsequently died. Resection is planned for two other patients at the present time.

Four patients who had a resection in 1948 subsequently had a second resection. One patient had a contralateral lobectomy for a reactivation that occurred after the first resection. The patient died of progressive disease fourteen months later. Segmental resection in three patients was followed by a recurrence of disease, in part, due to the technique used at that time and, in part, due to two patients leaving the hospital soon after operation. The third patient had two segments removed at the first operation and later had the lung removed. These three patients have negative sputum at present; both operations are included in the statistics for resection. Since Oct. 1, 1951, another Negro patient with progressive disease has had a pneumonectomy. A fourth Negro patient had bilateral disease and has had a bilateral upper lobectomy for disease that was present at the start of treatment. The second operation is not included in the statistics for resection. The indications for resection in these cases are given in Table X. In many instances thoracoplasty might have been used with good results. We do not believe that it would have been possible to preserve as much pulmonary function in as many cases if treatment by thoracoplasty had been selected. The preparation for making a wise decision about a plan of treatment for a case of pulmonary tuberculosis has been given by Alexander.[6] Briefly, this includes a review of all previous x-ray films, obtaining apical detail films, stereoscopic and body section films, recent bronchoscopy, several successive sputum or gastric content cultures, and study after a period of adequate bed rest. The value of bronchography has been shown by Gordon[21] and by Buckles[22] working with their respective associates.

TABLE X. INDICATIONS FOR RESECTION

INDICATIONS		NO.
Failure of collapse therapy		60
Thoracoplasty	14	
Pneumothorax or pneumoperitoneum	46	
Dense or solid lesions or for diagnosis		36
Destroyed lung		6
Middle or lower lobe disease		12
Unexpandable lung or empyema		5
Elective		12
Total		131

As stated by Alexander,[6] "resection is unquestionably the better operation under certain circumstances, thoracoplasty is better under other circumstances and there are other circumstances in which the choice of either operation would be a sound one. Unfortunately, neither operation can assure a patient that his sputum or gastric contents will become negative and remain so, even if his tubercle bacilli continue to be sensitive to streptomycin."

TABLE XI. THORACOPLASTY FROM JAN. 1, 1947, TO JAN. 1, 1952

GROUP	NO.	0-2 MONTHS P.O.						OVER 2 MONTHS P.O.				TOTAL DEATHS	
		SPREADS			DEATHS			SPREADS		DEATHS			
		NO.	PT. %	STAGE %	NO.	PT. %	STAGE %	NO.	PT. %	NO.	PT. %	NO.	PT. %
White	71	5	7.0	3.2	1	1.4	0.6	18	25.3	6	8.4	7	9.8
Negro	40	5	12.5	5.4	1	2.5	1.1	13	32.5	4	10.0	5	12.5
Total	111	10	9.0	4.0	2	1.8	0.8	31	29.3	10	9.0	12	10.8

The follow-up of the thoracoplasty group by race is given in Table XI. There were more operative and late spreads in the Negroes. Particularly disappointing has been the late result in the patients over 50 years of age (Table XII) with 20 per cent total deaths compared to 10.8 per cent for the entire group and compared with 8.6 per cent for those under 50 years of age. Better results have followed resection in a group of nine patients over 50 years of age as shown in Table XIII. The difficulty in obtaining good results in nonwhite patients, in patients with extensive disease, or with unstable disease conforms with the usual experience. Serious endobronchial disease was rarely present in the patients reported here, probably as a result of the beneficial effect of streptomycin and PAS. When present in major bronchi, it usually presents a serious hazard to successful treatment.

TABLE XII. RESULTS AFTER THORACOPLASTY IN PATIENTS OVER 50 YEARS OF AGE (36 STAGES)

		0-2 MONTHS P.O.						OVER 2 MONTHS P.O.				TOTAL DEATHS	
		SPREADS			DEATHS			SPREADS		DEATHS			
GROUP	NO.	NO.	PT. %	STAGE %	NO.	PT. %	STAGE %	NO.	PT. %	NO.	PT. %	NO.	PT. %
White	14	2	14	5.5	0	0	0	5	36	4	28.5	4	28.5
Negro	6	2	33	14.0	0	0	0	2	33	1	16.7	1	16.7
Total	20	4	20	7.8	0	0	0	7	35	5	25.0	5	20.0

TABLE XIII. RELATION OF RACE, THORACOPLASTY, EXTENT AND STABILITY OF DISEASE TO MORTALITY AND SUCCESS OF RESECTION FOR PULMONARY TUBERCULOSIS

		% WELL		MORTALITY	
GROUP	NO.	OF TOTAL	OF LIVING	OPERATIVE	TOTAL
Total resections	131	78.6	84.4	1.5%	6.9%
White	99	79.8	83.2	1.0%	4.0%
Negro	32	75.0	88.9	3.1%	15.6%
Thoracoplasty	71	81.7	85.3	1.4%	4.2%
No thoraco.	60	75.0	83.3	1.7%	10.2%
Bilateral	42	61.9	72.2	4.8%	14.3%
Unilateral	89	86.5	89.5	.0%	3.4%
Stable	108	88.0	91.3	.0%	3.7%
Unstable	23	34.8	44.4	8.7%	21.7%
Over 50 years	9	77.8	87.5	.0%	11.1%

A detailed breakdown of the results according to the type of resection and according to the antibiotic administered is given in Table XIV. It is realized that these groups are too small to be of statistical significance but we believe that the results shown in this table are in accord with the widespread belief that resection of some tuberculous lesions of the lung may be the most desirable form of treatment. We agree with Chamberlain and Klopstock[23] that segmental resection is a great aid to the patient with resistance.

The present location of patients is shown in Tables XV and XVI. The per cent of patients at home is slightly greater, and the per cent dead is less for the patients treated by resection. Approximately 20 per cent of both groups of patients are working and also approximately 20 per cent of both groups are in a hospital.

TABLE XIV. NUMBER OF PATIENTS WELL IN 1952 WHO HAD RESECTION FOR PULMONARY TUBERCULOSIS

	SM/PAS PROPHYLAXIS 1950-1951						SM PROPHYLAXIS 1947-1950							
	OPSM		PSM		RESISTANT		OPSM		PSM		RESISTANT		TOTAL	
OPER.	NO. PTS.	% WELL	NO. PTS.	% WELL	NO. PTS.	% WELL	NO. PTS.	% WELL	NO. PTS.	% WELL	NO. PTS.	% WELL	NO. PTS.	% WELL
Pn.	0		3	100	3	67	0		3	100	4	75	13	85
L & S	0		3	67	0		0		6	100	1	100	10	90
Lob.	8	100	8	75	7	71	12	92	14	42	3	33	52	71
Seg.	6	83	17	88	0		13	62	6	83	0		42	79
Exc.	12	83	0		0		5	100	1	100	0		18	89
Total	26	88	31	84	10	70	30	80	30	70	8	62	135*	79
			67 = 84%						68 = 74%				131*	

SM/PAS — Streptomycin, 1 Gm., twice a week,
Para-aminosalicylic acid, 7 Gm. daily
SM — Streptomycin, 1 Gm., daily
OPSM — No previous streptomycin given to the patient
PSM — Previously treated with streptomycin
RESISTANT — Tubercle bacilli causing the patient's disease were resistant to streptomycin, that is, some growth in media with 100 μg streptomycin or growth in the 10 μg tube equal to the growth in the control tube
Pn. — Pneumonectomy
L & S — Lobectomy and segmental resection
Lob. — Lobectomy
Seg. — Segmental
Exc. — Excision

*135 operations; 131 patients; four patients had two resections.

TABLE XV. THORACOPLASTY CASES FOLLOWED

YEAR	NO.	HOME		HOSPITAL	DEAD
		NOT WORKING	WORKING		
1947	23	8	7	4	4
1948	22	11	8	1	2
1949	13	6	3	2	2
1950	19	9	1	6	3
1951	16	7	0	8	1
Total	100*	41	19	21	12
%	100%	41%	19%	21%	12%

*Number of cases followed.

TABLE XVI. RESECTION CASES FOLLOWED

YEAR	NO.	HOME		HOSPITAL	DEAD
		NOT WORKING	WORKING		
1947-8	36	16	12	4	4
1949	28	10	9	5	4
1950	20	13	3	4	0
1951	47	25	5	16	1
Total	131	64	29	29	9
%	100%	48%	22½%	22½%	7%

DISCUSSION

Lee, Decker, Medlar, D'Esopo and their co-workers[24] have made a distinct contribution by their advocacy of the removal of certain small lesions which they have shown to be encapsulated but not healed. The Sunmount group believed in January, 1952, that streptomycin should be given in daily doses of 1 Gm. with 12 Gm. of PAS daily. This combination is given to patients until cavities disappear and the sputum becomes negative to culture. After these conditions have been present for four months the small residual necrotic lesions are removed surgically with a frequent finding of bacilli on smears that failed to grow on culture media. However, at the present time we feel that the results we have obtained in the patients who received 1 Gm. of streptomycin twice weekly with daily PAS justifies its continuation in most patients. We think that both drugs should be given at the time of surgery and without interruption if possible through the postoperative period. PAS is disagreeable to most patients and it is hoped that aldinamide, isonicotinic acid hydrazine or some new and effective drugs will make the treatment of tuberculosis less complicated.

Although the status of the treatment of tuberculosis is unsettled and many divergent opinions are held, we believe that the old basic rules of procedure are still indicated. Where routine bed rest alone for two or three months was indicated, probably now in most cases, some antibiotics should be given also. With continuation of this treatment some lesions will clear entirely. After medical treatment for several months it is obvious that certain lesions are irreversible. When this type of lesion is recognized the question arises whether one should require all such patients to remain for several months in the hospital receiving antibiotics when earlier resection can usually shorten the length of hospitalization and speed the safe return to work.

At present we are using a modified partial thoracoplasty or the modern thoracoplasty for over one-half of our patients. The use of small thoracoplasty stages

has made it possible for many patients to either arrest the disease or to reach a state where resection was a feasible operation. In order to preserve pulmonary function the number of ribs removed for apical disease has decreased in number. When a six- or seven-rib thoracoplasty does not result in cavity closure we prefer resection to a more extensive decostalization.

Fig. 2 is based on optimistically estimated future data about tuberculosis in the United States. Although there are 1 per cent deaths of the total United States population each year, the average life expectancy is 67 years. If one and one-half million people should have tuberculosis in some form and only 30,000 should die, say in 1953, the death rate would be 2 per cent each year. Should the number of known cases of tuberculosis at that time increase to 300,000, the yearly death rate would still be 10 per cent each year. And if only 15,000 of 90,000 patients with tuberculosis in hospitals should die, each year the fatality rate would be 16.7 per cent.

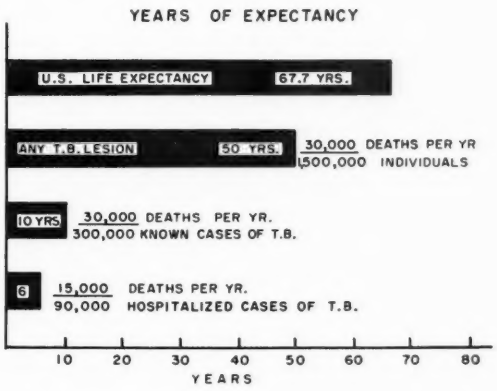

Fig. 2.

Faced with these probable "statistically significant" figures, one cannot but suspect that the yearly fatality rate in patients is at least seven or eight per cent per year or that the gross death rate from tuberculosis will show a more rapid decrease during the next few years.

SUMMARY

A report is given of 111 consecutive patients who had a posterior apical thoracoplasty and of 131 patients who had a pulmonary resection for tuberculosis between January, 1947, and October, 1951, and were followed to March 31, 1952.

The great majority of patients were men between 20 and 50 years of age with fibrocaseous disease.

Observation of 100 of the 111 patients treated by thoracoplasty gave 263 patient years of observation between six months and five years elaspsed time. The 131 patients treated by resection and observed from six to fifty months offered 256 patient years of observation.

Streptomycin was available for all of these cases, but was not used routinely at the time of thoracoplasty. Streptomycin daily was used for one group of resection cases, and streptomycin twice a week with daily PAS was used in the second group.

The operative mortality was 1.8 per cent for thoracoplasty and 1.5 per cent for resection. The late mortality was 9 per cent for thoracoplasty and 5.3 per cent for resection. Tuberculosis, cancer, alcoholism, and dope addiction caused all late deaths. Hemorrhage, shock, and transfusion reaction caused one operative death; progressive tuberculosis accounted for three operative deaths. The total fatality was 4.6 patients for thoracoplasty and 3.5 patients for resection for each 100 patient years of observation.

Operative spreads occurred in 9 per cent of patients treated by thoracoplasty and in 7.4 per cent of patients having a resection. Fistulas and empyema occurred infrequently in the last 66 patients having a resection.

Late spreads occurred in 29.3 per cent of patients treated by thoracoplasty and in 18 per cent of patients who had a lesion resected. Now inactive are 54 per cent of the patients who had a late spread following a resection, while 39 per cent of patients are inactive who had a late spread following a thoracoplasty.

Sixty-four per cent of the patients having thoracoplasty and 79 per cent of patients having a resection are inactive.

At home now are 41 per cent of the patients treated by thoracoplasty and 48 per cent of the patients treated by resection. Now working, in addition to the patients above, are 19 per cent of the thoracoplasty group and 22.5 per cent of the resection group.

Resection has been elected as a preferable procedure with increasing frequency. Concomitant partial thoracoplasty with resection in selected cases has given very satisfactory results.

The mortality and complications have been greater in nonwhite patients and in extensive, unstable, and bilateral disease. Resection in nine patients over 50 years of age was followed by better results than was thoracoplasty in patients over 50 years of age.

Intermittent streptomycin, 1 Gm. twice a week with daily PAS, has been used with 67 patients with better results than was obtained by short courses of 1 Gm. of streptomycin daily at the time of resection. It is hoped that new antibiotics will soon be available that are more palatable and more effective.

If the present early results of treatment are not temporary, the number of deaths from tuberculosis should continue to show a marked decline.

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PULMONARY RESECTION IN THE TREATMENT OF BLASTOMYCOSIS

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DURING the fifty-eight years which have elapsed since the original description of blastomycosis by Gilchrist and Stokes[1] (in 1894), a considerable volume of additional information has accumulated, but therapy of this disease has remained a consistently difficult and baffling problem. Many chemical agents have been employed with little success, and the newer antibiotics have likewise failed to influence significantly the usually grave prognosis. In the past best results have been obtained through the combined use of potassium iodide and blastomycin, and these agents have long represented the treatment of choice. However, even this type of therapy has failed to lower the mortality rate below 90 per cent in the systemic form of the disease.[2] The search, therefore, for more effective methods of management has continued, and recent advances in the field of chemotherapy hold promise of providing a more favorable outlook.

Hopkins and Murphy[3] have reported the effectiveness of undecylenic acid in a single case of disseminated blastomycosis, and the recent demonstration of antifungal properties of the aromatic diamidines has served to further brighten the situation. Schoenbach[4] has reported beneficial responses to stilbamidine in four cases of blastomycosis, and similar results have been obtained by one of us (J. H. S.). Other derivatives, including pentamidine, propamidine and 2-hydroxystilbamidine, have also been found to exhibit antifungal activity.[4, 5] However, favorable as these findings appear, many problems concerning toxicity and the development of organism resistance remain to be worked out, and it seems probable that chemotherapy alone will not always represent the best method of treatment. It would further seem reasonable that a pathologic process which produces destructive and granulomatous changes in the lungs would not be completely amenable to chemotherapeutic agents and could best be eradicated by surgical removal. Such a situation prevails in pulmonary tuberculosis, where resective surgical procedures have proved invaluable adjuncts in the control of lesions unresponsive to antimicrobial agents. Here, the use of streptomycin and para-aminosalicylic acid in combination with surgical therapy has rendered previously dangerous procedures relatively safe. If this situation proves to be a fair analogy, it would appear that the combined use of chemotherapy and resection should provide our closest approach to ideal management in many cases of blastomycosis.

From the Veterans Administration Hospital.

Reviewed in the Veterans Administration and published with the approval of the Chief Medical Director. The statements and conclusions published by the authors are a result of their own study and do not necessarily reflect the opinion or policy of the Veterans Administration.

Received for publication Nov. 12, 1952.

Unfortunately, there is a dearth of material in the medical literature concerning surgical treatment of pulmonary blastomycosis; it is feared that with the recent enthusiasm for chemotherapy provoked by the introduction of the diamidines, surgical management will be further de-emphasized and unexploited. Awareness of this possibility suggested to the authors that this might be an opportune time to present their experience with pulmonary resection in blastomycosis. Hopkins and Murphy[3] in April, 1952, reported two pneumonectomies for blastomycotic granulomas. One patient developed a postoperative transbronchial spread, which proved fatal in the absence of an effective chemotherapeutic agent. The second patient developed postsurgical evidence of disseminated disease, which showed a favorable response to undecylenic acid. Wood, Clagett, and Weed[5] give casual reference to a pulmonary blastomycotic granuloma which was removed surgically, but other than the radiologic picture, few details were set forth. To our knowledge, no other cases in which pulmonary resection was employed have appeared in the literature. In view of this discovery of a generally limited experience in this field, our contribution of two cases—one with a highly satisfactory result—seemed to assume a proportionate and unexpected significance.

Reported herewith are two cases of pulmonary blastomycosis in which lobectomy was performed:

CASE REPORTS

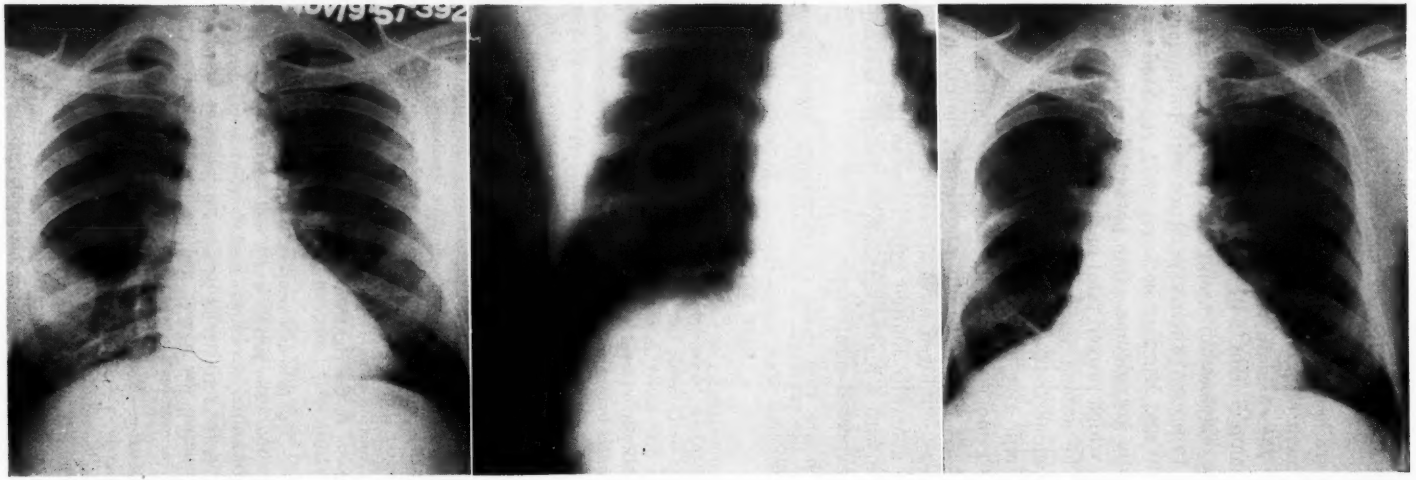
CASE 1.—

History.—A. P. (29936), a 56-year-old Negro janitor, was admitted to the Veterans Administration Hospital, New Orleans, La., on Nov. 27, 1951, for evaluation of a lesion in the right lung which was discovered on a routine roentgenogram of the chest. Although he did not consider himself ill, careful questioning elicited a history of the onset of a mild cough about one month before entry. Fifteen days prior to admission the patient also suffered a brief episode of fever, chills, and mild retrosternal discomfort, which prompted him to consult his private physician. A roentgenogram of the chest was not obtained at that time, and the patient was simply advised that he had high blood pressure. Therapy consisted of sedation and bed rest for three days, at the end of which time he was allowed to return to his work as a janitor at the hospital. Although the cough and mild retrosternal pain had persisted, the patient attached no further significance to these symptoms as a result of his doctor's reassurance. Sputum remained scanty and of a white mucoid character. The patient denied wheezing, hemoptysis, or dyspnea, and had no recurrence of chills and fever after the initial episode.

On Nov. 19, 1951, a routine annual roentgenogram of the chest was obtained. This examination revealed a lesion in the right lower lung field (Fig. 1, *A*), and hospitalization was recommended.

Physical Examination.—The patient's temperature was 98.8° F., the pulse was 84, and the blood pressure was 170/100. The patient was a well-developed, well-nourished individual, who appeared to be in good health. Examination of the chest revealed a distinct inspiratory lag of the right hemithorax, but no abnormalities to percussion or auscultation were noted. A grade 1 aortic systolic murmur was present, and the prostate gland was slightly enlarged. The remainder of the physical examination was essentially negative.

Initial Laboratory Studies.—Roentgenograms of the chest revealed a sharply circumscribed density, approximately 3 cm. in diameter, in the right lower lobe. These films showed some evidence of a decrease in the size of the lesion when compared with the previous routine roentgenogram. The left lung appeared free of pathology, and there was no evidence of hilar or mediastinal involvement. Planigrams of the chest (Fig. 1, *B*) disclosed the presence of a small area of lucency within the lesion, but yielded no further information.



A. *B.* *C.*

Fig. 1.—Roentgenograms on Case 1. *A*, Routine annual film on which a lesion was discovered in the right lower lung field. *B*, Body section roentgenogram which demonstrates a sharply circumscribed nodule in the right lower lobe. Subsequent lobectomy established a diagnosis of North American blastomycosis. *C*, Follow-up film taken nine months after resection of the right lower lobe. No evidence of residual or recurrent disease can be detected. Patient working and clinically well.

Hemogram was as follows: red blood cells, 5,400,000; hemoglobin, 15.5 Gm.; hematocrit, 44; white blood cells, 12,600; neutrophils, 65 per cent; eosinophils, 1 per cent; monocytes, 1 per cent; lymphocytes, 33 per cent; erythrocyte sedimentation rate, 34 mm. per hour.

The electrocardiogram was consistent with left ventricular hypertrophy.

Sputum culture was positive for alpha-hemolytic streptococci and nonhemolytic staphylococci. Six consecutive sputum specimens for malignant cells, and two sputum concentrates for acid-fast bacilli, were negative.

Skin tests with histoplasmin and coccidioidin were negative. Skin test with first-strength tuberculin was positive.

Liver function studies, blood urea nitrogen, serum proteins, serologic test for syphilis, intravenous and retrograde pyelograms, and urinalysis, were either negative or within normal limits.

Hospital Course.—During the early part of hospitalization the patient remained afebrile and his mild symptoms were essentially unchanged. Bronchocopy failed to reveal any abnormalities. Subsequent roentgenographic studies of the chest disclosed no further change in the appearance of the density in the right lower lobe. Although the lesion was thought to be of inflammatory origin by several observers, opinions were divided, and the presence of a bronchiogenic carcinoma could not be ruled out. In accordance with current trends in the management of such lesions, early surgical intervention was recommended.

On Dec. 17, 1951 (twenty days after admission), an exploratory thoracotomy was performed. Preliminary resection of the right lower lobe was carried out and frozen section of the lesion revealed a granulomatous type of reaction. Since no evidence of disease was noted by the surgeon in the remaining lobes, the chest was closed without further sacrifice of pulmonary tissue.

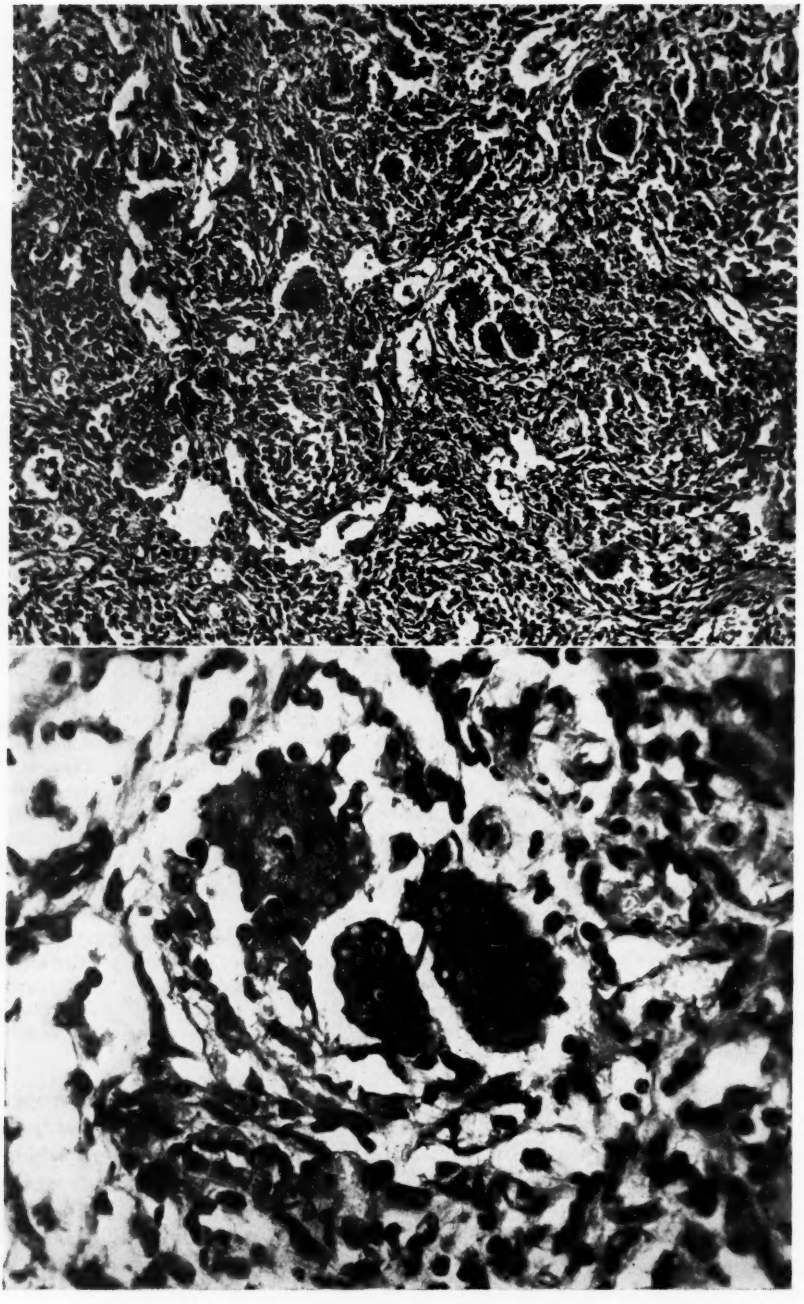
Gross examination of the surgical specimen disclosed a solid, circumscribed nodule, 3 cm. in diameter, located peripherally in the mid-portion of the resected lobe. Adjacent to the larger lesion there were several similar, but smaller, nodules averaging ½ cm. in diameter. Study of microscopic sections revealed a granulomatous type of lesion with areas of fibrosis and necrosis and many giant cells (Fig. 2, *A* and *B*). Innumerable spherical, double-contour, intracellular bodies were scattered throughout the tissue. These structures appeared as thin-capsuled, budding (broad-based) yeast forms (Fig. 3), and were interpreted as typical of North American blastomycosis.* Cultures of the surgical specimen for fungi and acid-fast organisms were negative. Postoperative blood and sputum cultures for fungi were also negative, as were skin tests and complement fixation for blastomycosis.

The patient's postoperative course was essentially uneventful, and the remaining lobes of the right lung exhibited rapid and complete re-expansion. A three-month period of complete bed rest was enforced, during which time the patient remained afebrile, asymptomatic and gained nineteen pounds in weight. Three additional months of graduated activity ensued, following which he was allowed to begin work as an elevator operator. He continued to enjoy excellent health, and serial roentgenographic examinations of the chest have failed to disclose evidence of recurrent disease. The latest follow-up examination was conducted on Sept. 15, 1952, nine months after lobectomy (Fig. 1, *C*).

Comment.—Although the correct diagnosis was not established preoperatively in this case, early intervention for a suspected malignancy probably had the fortunate consequence of eradicating the blastomycotic process while it was still localized. It is emphasized that a highly satisfactory result was obtained even though no form of therapy other than lobectomy and bed rest was employed. The benefit to be derived from the postoperative administration of a fungicidal agent in a situation of this kind is a subject for speculation, but such a plan would seem to be wise in the light of our present knowledge.

*This diagnosis was concurred in by the Armed Forces Institute of Pathology.

A.



B.

Fig. 2.—Photomicrographs of tissue sections in Case 1. *A*, Typical granuloma formation. Many giant cells can be seen. (Hematoxylin and eosin stain.) *B*, High-power photograph of a group of giant cells seen in Fig. 2, in *A*. These cells contain many yeast forms of *Blastomyces dermatitidis*.

CASE 2.—

History.—F. L. (24520), a 49-year-old white bartender, was admitted to the Veterans Administration Hospital, New Orleans, La., on Feb. 10, 1951. He complained of feverish sensations of three or four months' duration, associated with weight loss (ten to fifteen pounds), a mild nonproductive cough, listlessness, fatigue, night sweats, mild aching pain in the region of the right breast, and vague "burning" sensations over the anterior portion of the trunk and legs. The pain in the right chest was made only slightly worse by deep inspiration and coughing, and the patient denied expectoration, hemoptysis, dyspnea, or wheezing. He had been a chronic alcoholic since 1943, drinking an estimated fifth of whisky each day until the onset of the present illness, at which time he decreased his consumption of alcohol to several drinks daily. He had been aware of a poor appetite for several years, but anorexia had increased during the few months prior to admission. One month before entry he visited his private physician, who obtained a chest film, told the patient he had a "spot" on his right lung, and recommended hospitalization for suspected pulmonary tuberculosis.

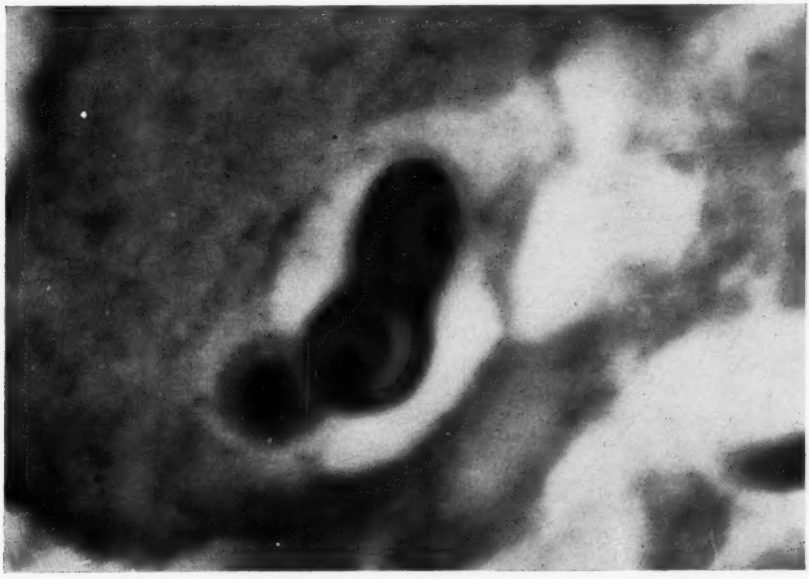


Fig. 3.—Very high magnification of a portion of a giant cell which contains a thin-capsuled, budding yeast form (Schiff stain). Note the broad-based attachment of the bud. This is typical of North American blastomycosis (Case 1).

Physical Examination.—The patient's temperature was 99° F., the pulse was 90, the blood pressure was 118/82. The patient was an emaciated individual who appeared chronically ill and who coughed occasionally. Examination of the chest disclosed some evidence of emphysema, but no asymmetry, râles, or friction rub was detected. Except for the presence of a small inguinal hernia and varicose veins of the right calf and ankle, no other significant physical abnormality was noted.

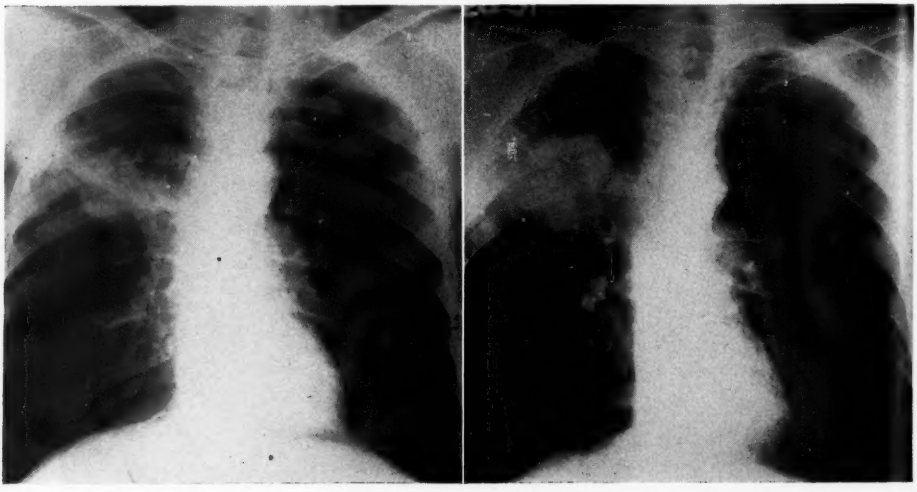
Initial Laboratory Studies.—Roentgenograms of the chest revealed an irregular lesion in the anterior segment of the right upper lobe (Fig. 4, *A*). This shadow appeared generally dense but contained some poorly defined areas of lucency. Planigrams confirmed the presence of the lucencies and showed evidence of a masslike density extending throughout the depth of the right upper lobe. There appeared to be some constriction and irregularity of the right upper lobe bronchus.

A skin test with first-strength tuberculin was positive. Skin tests with histoplasmin and coccidioidin were negative.

Sputum studies for malignant cells were negative. The patient was unable to produce satisfactory sputum specimens for acid-fast smears, but direct examination of gastric washings disclosed the presence of a few acid-fast bacilli on two occasions. However, this finding could not be confirmed by subsequent cultures.

Hemogram was as follows: red blood cells, 4,500,000; hemoglobin, 13.5 Gm.; hematocrit, 43; white blood cells, 12,950; neutrophils, 78 per cent; lymphocytes, 20 per cent; monocytes, 1 per cent; eosinophils, 1 per cent; erythrocyte sedimentation rate, 39 mm. per hour. Total serum proteins were 5.7 Gm. per cent with 3.4 Gm. of albumin and 2.43 Gm. of globulin. Total serum bilirubin was 1.37 mg. per cent, and a 45-minute sulfobromophthalein sodium test revealed 7.7 per cent retention, but other liver function studies were normal.

An electrocardiogram, urinalysis, and B.U.N. disclosed no abnormality.



A. *B.*

Fig. 4.—Serial roentgenograms on Case 2. *A*, Admission chest film revealing an irregular lesion in the right upper lobe. *B*, Marked progression of the lesion despite antibiotic therapy.

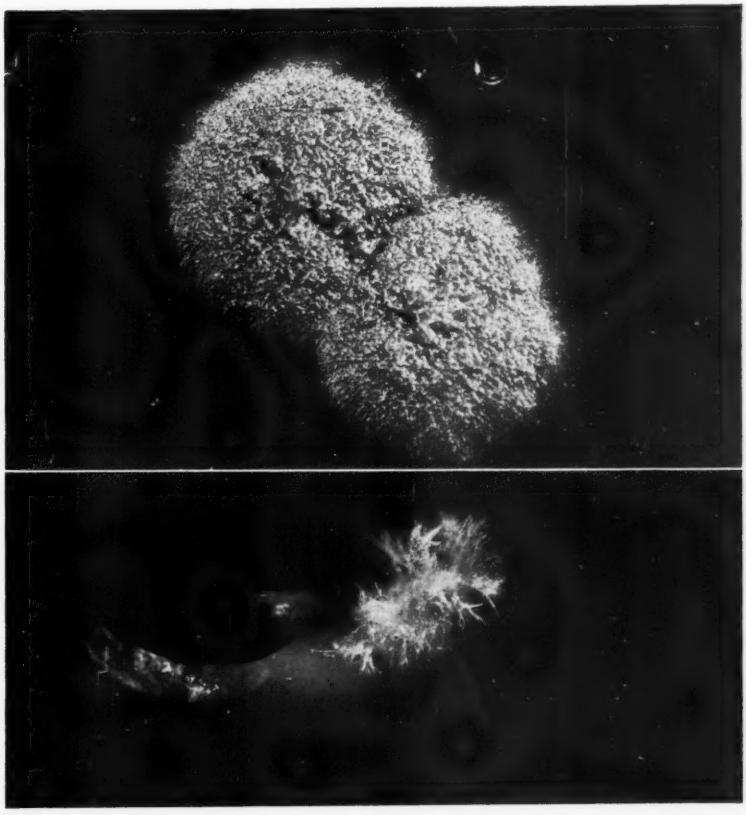
Hospital Course.—Following admission, the patient exhibited daily temperature elevations of 100 to 102° F. and continued to lose weight. Serial roentgenograms of the chest showed rapid progression of the disease process in the right upper lung (Fig. 4, *B*) despite the administration of penicillin and Chloromycetin.

A bronchoscopy on Feb. 18, 1951, revealed considerable reddening and granularity of the mucosa surrounding the orifice of the right upper lobe bronchus, but studies of the secretions from this area for acid-fast bacilli, fungi, and malignant cells, were negative.

At this point, a diagnosis of bronchiogenic malignancy with secondary infection was generally favored over a primary inflammatory process, although the latter condition was strongly supported by one of us. Surgical intervention was recommended, but in view of the fact that pulmonary tuberculosis had not been satisfactorily ruled out, streptomycin and para-aminosalicylic acid were begun on March 2, 1951, as a preoperative precautionary measure. On March 21, 1951, an exploratory thoracotomy was performed. The apical and anterolateral aspects of the right upper lobe were found to be adherent to the thoracic wall. The endothoracic fascia in these areas was dissected away, and a right upper lobe resection was carried out. Frozen sections were interpreted as inflammatory granuloma, and since no disease could be palpated in the remaining portions of the right lung, no further resection was attempted.

Gross examination of the surgical specimen disclosed the presence of a large indurated area in the mid-portion of the resected lobe. On sectioning, this lesion had a gray-black appearance and showed scattered areas of necrosis but no definite zones of cavitation. Microscopically, this tissue was consistent with a blastomycotic granuloma, and cultures of pus from the lesion were positive for *Blastomyces dermatitidis* in both the yeast and mycelial phases (Fig. 5, *A* and *B*).

A.



B.

Fig. 5.—North American blastomycosis isolated from resected right upper lobe (Case 2). *A*, Twenty-day growth on blood agar at 37° C. (Yeast phase.) *B*, Twenty-day growth on Sabouraud's medium at room temperature. (Mycelial phase.)

There was excellent postoperative re-expansion of the remaining lobes of the right lung and no evidence of residual disease was detected therein (Fig. 6, *A*). Daily low-grade temperature elevations disappeared after the first postoperative week under antibiotic therapy. Cultures of the sputum were negative for fungi. Since the patient was essentially asymptomatic and had no evidence of recurrent disease on postoperative roentgenograms of the chest, he was discharged from the hospital on April 14, 1951 (twenty-fourth postoperative day), with instructions to follow a program of modified bed rest at home.

Within a week after discharge the patient noted gradual onset of malaise, fever, and a mild cough which was productive of a small amount of blood-tinged sputum. Because of these symptoms, he was readmitted to the hospital on May 2, 1951.

Physical examination on this occasion revealed the residuals of the previous thoracic surgery, a mild inspiratory lag over the right upper chest and decreased breath sounds over the entire right hemithorax. The latter finding was most marked posteriorly, where fremitus was also somewhat decreased. Temperature was 99° F. Otherwise, physical findings were not significantly different from those of the previous hospitalization.

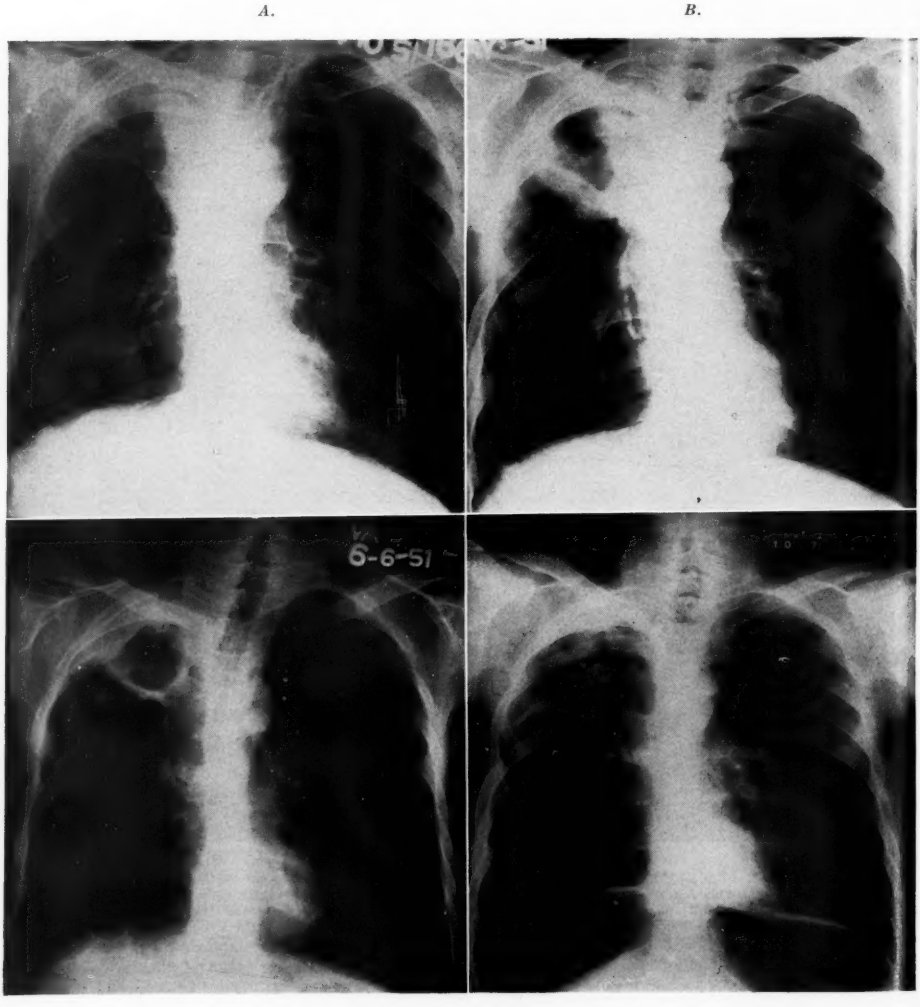


Fig. 6.—Serial roentgenograms on Case 2. *A*, Chest film taken twenty days after right upper lobe resection for blastomycotic granuloma. *B*, Readmission film, forty-three days after lobectomy, reveals recurrence of a density in right upper lung. Note the huge area of cavitation. *C*, One month later (seventy-seven days after surgery) there is evidence of enlargement of the cavity and spread of the disease process throughout the right lower lung. This film was taken shortly after institution of human convalescent serum, iodides, and blastomycin. *D*, Chest film nineteen months after lobectomy discloses complete disappearance of the cavity and clearing of scattered lesions in the right lower lung. Only a small stable density remains in the right apex, with overlying pleural thickening. Therapy has been discontinued and the patient appears clinically well.

Roentgenograms of the chest at this time disclosed a confluent density which occupied the entire upper one-third of the right lung field. Within this density there was a large (4 by 6 cm.) circular zone of lucency, which was interpreted as representing a huge cavity (Fig. 6, *B*). These findings appeared to be localized within a contracted and almost totally destroyed right middle lobe.

A sputum culture was positive for *Blastomyces dermatitidis*. Complement fixation test for blastomycosis was also positive. A skin test with blastomycin was negative, as were blood cultures for fungi.

During the early part of hospitalization, daily temperature elevations to 101° F. were noted, and the patient remained symptomatic. A repeat roentgenogram of the chest taken one month after admission revealed enlargement of the cavity in the right apex, together with the appearance of scattered areas of infiltration throughout the right lower lung (Fig. 6, *C*). The latter finding was interpreted as evidence of bronchial dissemination of the disease process. Fortunately, a small quantity of human convalescent serum was available at this time, and 125 c.c. of this material were administered on May 23, 1951, and again on May 25, 1951. Two days later, potassium iodide was begun in an initial amount of 15 drops daily, with gradual increase in dosage until the patient was receiving more than 550 drops each day. At this time, the administration of blastomycin was also initiated in gradually increasing quantities. Within three days after receiving the human convalescent serum the patient began to exhibit rapid and somewhat unexpected symptomatic improvement. His fever gradually subsided, and a weight gain of twelve pounds was recorded within a two-month period.

By July 26, 1951, the skin test with blastomycin had become positive, and the therapeutic administration of that antigen was then discontinued. A sputum culture was positive for *Blastomyces dermatitidis* on Aug. 17, 1951, but thereafter serial cultures of sputum were consistently negative for fungi. Complement fixation for blastomycosis was found to be negative on Nov. 7, 1951.

Corresponding to the clinical improvement noted, serial roentgenographic studies of the chest disclosed rapid and marked regression of the density in the right upper lung field, and the cavity was eventually lost to radiographic view. Complete clearing of the scattered lesions in the right lower lung field was observed. In order to obtain relaxation of the hyperexpanded right lung and further promote healing of the disease process, a pneumoperitoneum was induced on Nov. 15, 1951.

The patient continued to do well until February, 1952, when he developed grippal symptoms and temperature elevations for about two weeks. Shortly thereafter, the presence of a small right-sided pleural effusion was detected. This material was removed by thoracentesis on three occasions. About 50 c.c. of clear, thin, pale yellow fluid was obtained at each aspiration. Examination of one of these specimens disclosed 230 cells per cubic millimeter, 40 of which were neutrophils, and 190 of which were lymphocytes. The specific gravity was 1.010, the total protein, 0.8 Gm. per cent. Cultures for fungi were negative. Residual fluid in the right pleural cavity gradually disappeared and thereafter the patient had no further difficulty.

On June 13, 1952, potassium iodide was discontinued and the regimen of modified bed rest, which had been maintained throughout the period of hospitalization, was gradually relaxed. The patient continued to improve from a clinical standpoint, and at the present writing he appears perfectly well. Recent roentgenograms of the chest reveal a small, stable area of density in the right apex with some overlying pleural thickening (Fig. 6, *D*). Early discharge from the hospital is contemplated.

Comment on Second Case.—Although this patient derived considerable overall benefit from the therapeutic measures employed, preoperative and postoperative use of some of the more effective fungicidal agents now available might have prevented the postsurgical flare-up of the disease process. Should reactivation of the residual lesion occur in the future, one of these preparations will be administered and further surgical intervention considered.

The patient's premature release from the hospital and the failure to enforce a more prolonged and rigid regimen of bed rest during the initial admission certainly reflects a lack of wisdom in dealing with this disease and may have contributed to the early relapse. The use of pneumonectomy in place of lobectomy might have produced a more favorable result in this case, but operative findings did not seem to justify the more radical procedure. The use of a postlobectomy thoracoplasty might have prevented reactivation of the disease process by limiting overdistention of the remaining lobes. While no specific answers to these matters can be given, there is room for fruitful speculation. The need for early and accurate diagnosis is clear and requires no elaboration.

DISCUSSION

It is worthy of note that in both the cases presented, the patients carried a diagnosis of possible bronchiogenic carcinoma to the operating room. Although various primary inflammatory conditions, including pulmonary mycosis, were given some consideration, the presence of a malignant lesion could not be ruled out in either case. The manner in which blastomycosis may mimic carcinoma is thus clearly borne out, as is the necessity of seriously considering this disease in the differential diagnosis of suspected pulmonary neoplasms. It is also pointed out that blastomycosis may closely simulate pulmonary tuberculosis in its clinical behavior and roentgenographic appearance.

In attempting to evaluate the wisdom of surgery in pulmonary blastomycosis, and establish criteria for selection of cases, it occurred to us that a rather close parallel can be drawn between the two types of blastomycosis presented here and two pathologic types of pulmonary tuberculosis. The discrete, well-localized, nodular lesion which was resected in Case 1 might be compared to a discrete, nodular form of tuberculosis (tuberculoma); while the intense, diffuse, rapidly progressive lesion of Case 2 might be compared to the acute exudative form of caseous pneumonia. Therapeutic results obtained here would again be comparable to those expected from pulmonary resection, if employed in the two described forms of tuberculosis, that is, excellent result in the discrete nodular form, and poor result, with extension or recurrence, in the acute pneumonia form.

Assuming an accurate preoperative diagnosis, and following the supposed similarity of the two diseases and the wide experience which has been gained in the surgical therapy of tuberculosis, it would seem that surgical intervention would have been a wise choice in Case 1 and a poor choice in Case 2. However, resection might have been indicated later in the second case following preliminary treatment with chemotherapeutic agents in much the same manner as streptomycin and para-aminosalicylic acid are employed in tuberculosis. The preoperative use of diamidines, iodides, and blastomycin might have converted the original intensely active process to a more localized and chronic form, which would have been better suited to resection and presented a more favorable prognosis. Further support of this contention is gained from the postoperative course of Case 2, wherein iodide and vaccine therapy converted the acute recurrence of the lesion to a chronic, stable, well-localized status, the form suitable for resection.

Thus it would appear that the same methods which have placed pulmonary resection in tuberculosis on a firmer footing might be successfully employed in pulmonary blastomycosis. As always, the intelligent integration of all resources at our command provides the best results in the struggle with a difficult therapeutic problem.

SUMMARY AND CONCLUSIONS

1. Two cases of blastomycosis in which pulmonary resection was employed are presented. One case, with a discrete nodular lesion, obtained an excellent result. The second case, with acute progressive disease, suffered an early relapse.

2. To our knowledge, the two cases reported here are the first to appear in the literature wherein lobectomy was employed in the treatment of pulmonary blastomycosis. Case 1 is the first reported in which resection alone effected an apparent cure.

3. Pulmonary blastomycosis may closely simulate bronchiogenic carcinoma in its roentgenographic appearance and must be considered in the differential diagnosis of the latter condition.

4. The excellent result obtained in one of our cases suggests that pulmonary resection should be strongly considered in the therapy of some cases of blastomycosis. This patient has been restored to health and employment after lobectomy; no other form of therapy was utilized.

5. The prompt recurrence of disease in Case 2 seems to indicate that resection alone does not represent wise or suitable therapy in dealing with intense, poorly localized, progressive blastomycotic lesions.

6. It is our opinion that the management of blastomycosis should simulate that of pulmonary tuberculosis. With this point of view in mind, it is suggested that the combined use of drug therapy (diamidines, iodides, and vaccine) and resection might offer more favorable results in pulmonary blastomycosis, just as streptomycin and para-aminosalicylic acid combined with surgery have improved the prognosis of tuberculosis.

We are indebted to Dr. Joseph Ziskind and Miss Elsie Buff of the hospital Laboratory Department for their aid with the pathologic material used in this report. We also wish to express appreciation to Mr. Frederick W. Busic of the Photographic Laboratory for his assistance in the preparation of the illustrations used herein.

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RECOVERY FROM EXPERIMENTAL ATELECTASIS

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Groningen, Netherlands

INTRODUCTION

EXPERIMENTAL research on the genesis of atelectasis was initiated by Lichtheim in 1879.[1] He observed that, after obstruction of the bronchi, atelectasis only occurred when the blood perfusion remained intact. He also noticed differences in the rate of development of atelectasis when the lungs had inhaled carbon dioxide, oxygen, or nitrogen before the obstruction of a bronchus; he explained the various rates of development of atelectasis by the differences in the absorption rate. The problem was taken up again by Coryllos and Birnbaum (1928-1932).[2-5] Their improved technique enabled them to extend the results of Lichtheim. Other problems related to the genesis of atelectasis have been studied by Lee, Ravdin, Tucker, and Pendergrass (1928),[6] and by van Allen and Adams (1930).[7] Their results, however, do not influence the general views laid down by earlier authors. A new aspect has been introduced by van Allen and Jung (1931)[8] who demonstrated the existence of collateral ventilation. These studies were confirmed and extended by Baarsma and Dirken (1947),[9] and by Baarsma, Dirken, and Huizinga (1947).[10]

Only little experimental research has as yet been done on the recovery from atelectasis. Lee and his co-workers (1928) mention that slight positive pressure may support the re-expansion although roentgenographic inspection still may show some atelectatic rests. Lindskog and Bradshaw (1934)[11] produced atelectasis in rabbits, cats, and dogs by resorption of oxygen from obstructed parts. The animals were sacrificed and the lungs removed. Either by positive or by negative pressure the atelectatic part was then made to expand again. This occurred at a critical pressure of about 14 cm. of water. Identical results were obtained when the attempt at reinflation was made some two to twenty-six days after the production of the atelectasis.

METHODS

Dogs were used in these experiments because of their large bronchial tree. An initial subcutaneous dose of morphine (2 mg. per kilogram), chloralosane (50 mg. per kilogram), and Nembutal (20 mg. per kilogram) produced the rather steady and mild anesthesia, which was desired in order to maintain a good condition in the animal throughout the prolonged experimental period. Occasionally an additional dose of Nembutal (10 mg. per kilogram) was injected.

In one series of experiments we attempted the production of atelectasis by slowly sucking gas out of a lobe by means of a catheter fitting airtight in one of the bronchi. It was found that only an incomplete atelectasis resulted, and a second series of experiments was started. In this series, deflation of the lobe was preceded by a period of twenty minutes during which the animal breathed oxygen. Using this method the gas left in the deflated

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This study was supported by a grant from the Netherland Organization for Pure Research (Z.W.O.).
Received for publication Aug. 11, 1952.

lobe was absorbed completely within twenty minutes. During these twenty minutes the negative pressure, used for the deflation, was maintained. The existence of a complete atelectasis could be proved by microscopic examination.

At the beginning of this investigation the bronchial trees of a number of dead animals were bronchoscopically examined in order to determine the lobe most suited for the insertion of a catheter. The results were checked by autopsy. Since the upper lobes are difficult to enter and the bronchi of the middle and cardiac lobes are rather narrow, only the inferior lobes could be used. The left inferior lobe was chosen, because only here could a sufficient length of bronchus be found for the insertion of a catheter without interfering with the ventilation of the unoccluded parts. Sections of the lung, smaller than a complete lobe, could not be used because of the occurrence of collateral ventilation.

The distance from the origin of the bronchus of the left upper lobe to the origin of the apical bronchus of the left inferior lobe commonly is less than 0.5 to 1 cm. Therefore the airtight grip of the catheter had to be exerted locally; it is obvious that an inflated cuff, used in several other investigations, was not applicable in this type of experiment. Moreover, these catheters were easily displaced when even a slight positive or negative pressure was raised beyond the tip of the instrument. For these reasons metal catheters were constructed (Fig. 1), which were able to exert a firm local grip.

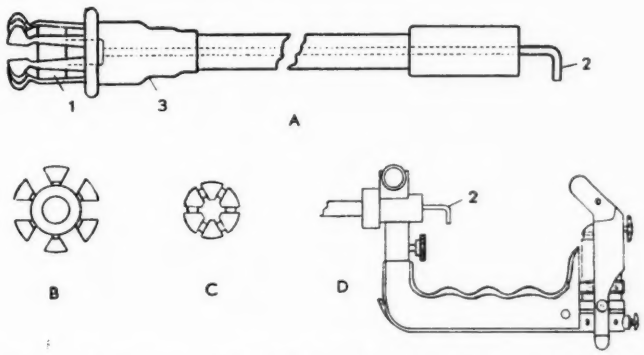

Fig. 1.—The bronchus catheter. *1*, Metal ring for expanding the teeth. *2*, Rod connected to expansion ring. *3*, Rubber sleeve for covering the teeth (partially rolled back).

When the inner ring, *1* (Fig. 1, *A*), was pulled back the tip consisted of a circle of metal teeth of small diameter (Fig. 1, *C*). The diameter could be increased (Fig. 1, *B*) by pushing down the rod, *2* (Fig. 1, *A*). The teeth were surrounded by a thin-walled rubber tube, *3*, which extended a few centimeters up the stem of the catheter and can be seen rolled back in Fig. 1, *A* in order to show the construction. In this manner a local increase of the tip diameter to over 150 per cent of the initial value could be obtained. By making a number of these tips of various calibers, which all fit on the same catheter stem, an airtight fit could be insured in bronchi of various sizes.

After the induction of the anesthesia the animal was tracheotomized and the condition of the air passages was bronchoscopically inspected. At the same time the distance to the future site of the catheter tip was measured. Then the tube of the Brünings bronchoscope was replaced by the catheter (Fig. 1, *D*) with the tip in the closed position. By slightly spreading the tip, the position could be examined and eventually corrected by looking through the catheter. After attaining the correct position the catheter was fixed by pushing the rod, *2*, thereby fully spreading the tip. The fit was tested for airtightness by applying a positive or negative pressure of about 10 cm. of water.

The animal was now connected to the apparatus, reproduced schematically in Fig. 2. The apparatus consisted essentially of two separate circuits, one for the left inferior lobe

and the other for the remaining parts of the lungs. These parts inhaled air or gas mixtures through valve *5* and stopcock *7* and exhaled through valve *6* and stopcock *8* either into the outer air or into a tidal air spirometer from which the expired volume was automatically expelled during the next inspiration. The system of the isolated lobe contained the catheter, *1*, which if the clamp, *2*, was removed could be connected to a spirometer, *3*, of 750 ml. capacity. A mercury burette, *10*, was used to empty the lobe. The pressure in the lobe during the emptying could be read from a mercury manometer, *9*. When the gas was gradually removed from the lobe the pressure fell very slowly at first until quite suddenly, after the removal of some 50 ml. of gas, the manometer showed an abrupt fall in pressure. The pressure was then kept at a level of –4 cm. of mercury for ten minutes. After this period the lobe was connected with the spirometer, *3*, and the registering of eventual changes in volume of the lobe was started.

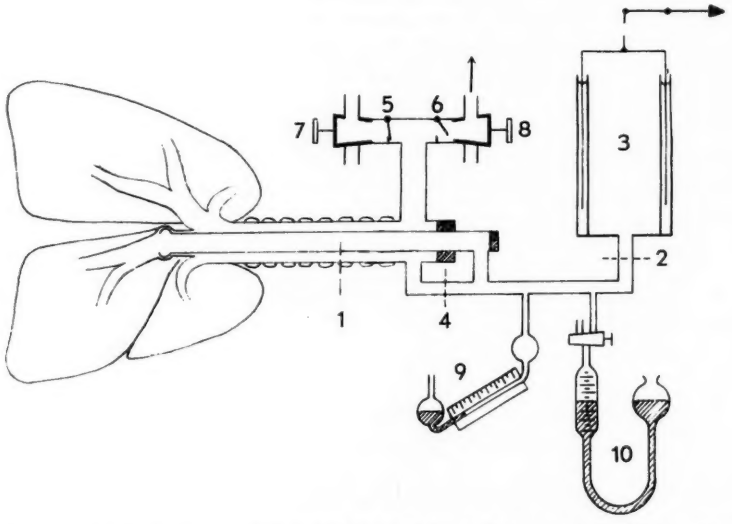

Fig. 2.—Apparatus for producing atelectasis and for studying re-expansion. *1*, Bronchus catheter. *2* and *4*, Position of clamps. *3*, Spirometer. *5* and *6*, Respiratory valves. *7* and *8*, Respiratory stopcocks. *9* and *10*, Manometer and burette for deflation.

In the series of experiments on resorption atelectasis both systems were joined by removing clamp, *4*. The combined systems were then washed out for about twenty minutes with oxygen from a bag connected to stopcock, *7*. After this, clamp *4* was replaced; the lobe was emptied by means of the burette; and a period of twenty minutes was allowed for the development of the resorption atelectasis.

In both series of experiments, either with incomplete or with complete atelectasis, an attempt was made to compare the efficiency of different procedures for restoring normal expansion to the atelectatic lobe. It was felt that comparable data could be obtained only when the effect of these procedures was studied in the same animal under conditions as nearly identical as possible. For this reason the previously mentioned techniques for establishing atelectasis had been developed. Usually the production and removal of an incomplete atelectasis could be completed within twenty minutes. The establishment of resorption atelectasis and its subsequent re-expansion could be performed in fifty to sixty minutes. A number of these experiments therefore could be done on the same dog. Moreover, since the sequence

of the procedures for obtaining re-expansion was often varied, the resulting data may be regarded as comparable even considering the fact that the condition of the animal and especially the condition of the lobe declined during the prolonged period of experimentation.

The main procedures, whose efficiency in restoring normal expansion of the atelectatic lobe was compared, were: normal spontaneous breathing, hyperpnea by excess carbon dioxide, hyperpnea by lack of oxygen, and stenosis of the airway.

After the establishment of atelectasis, the lobe was connected with the spirometer, *3*, by removal of the clamp, *2* (Fig. 2). The other lobes of the lungs were normally ventilated with air, the animal breathing spontaneously, while the expiratory tidal volume was recorded by a tidal air spirometer. The expansion of the atelectatic lobe produced a fall of the spirometer bell, *3*, and therefore a rise of the recording stylus. In this way the effect of normal spontaneous breathing on the recovery of the atelectatic lobe was studied.

If, instead of air, a mixture of 10 to 15 per cent carbon dioxide in air was presented from a bag connected to stopcock *7*, the resulting hypercapnic hyperpnea effected the re-expansion of the atelectatic lobe; this was recorded by the spirometer, *3*. By having the animal breathe mixtures low in oxygen the effect of hypoxic hyperpnea was studied. Best results were obtained with mixtures of about 4 per cent oxygen in nitrogen.

In experiments on stenotic breathing the effect of inspiratory or expiratory obstruction could be studied by closing either stopcock *7* or *8*. Since this procedure caused violent ventilatory efforts, the period of complete obstruction was limited to about thirty to forty-five seconds.

The pleural pressure was measured in some of the experiments through periods of several hours by means of a small, thin-walled, rubber balloon, introduced into the pleural cavity under positive pressure ventilation and connected to a recording capsule via a U tube filled with water.

The animal was sacrificed at the end of an experiment by intravenous injection of 20 to 30 c.c. of a 20 per cent solution of magnesium sulfate in order to avoid the occurrence of gasps, which might affect the microscopic picture of the lobe. In every instance autopsy was performed to inspect the correct site of the tip of the catheter and the condition of the lungs, especially of the left inferior lobe. Macro- and microscopic examinations were made repeatedly, with the lungs either in the atelectatic or in the re-expanded state.*

RESULTS

A. Incomplete Atelectasis.—Slow deflation of a lobe produced only an incomplete atelectasis. Part of the original gas content was trapped in the collapsing lobe. Presumably some of the thin-walled smaller air passages collapse before the air spaces beyond them are completely emptied. Photomicrographs of the lobe tissue show multiple atelectatic foci with air spaces in between (Fig. 3).

An example of the results obtained in this type of atelectasis is shown in Fig. 4. Assuming the total volume of the lobe-spirometer system as constant, a rise of the spirometer record (middle curve) corresponds to an increase in the volume of the lobe. In Fig. 4, *A* the lobe was connected to the spirometer at signal *1*. The abrupt initial rise, *a*, of the curve was due to air flowing from the spirometer into the patent part of the lobe's airways which had been kept at −4 cm. of mercury and which were now restored to atmospheric pressure. In the next three minutes the re-expansion of the lobe, from which 55 ml. of gas had been removed by the deflation procedure, amounted only to 17 ml., the

*We are indebted to Dr. H. Hadders of the Pathologic Institute for his great willingness to make and discuss the numerous macro- and microscopic examinations.

greater part of which was right at the beginning. Even forty-five minutes of normal spontaneous breathing in this type of experiment were never sufficient to bring about full expansion of the atelectatic lobe. In Fig. 4, *A* the conditions for re-expansion were very favorable, since this was the first experiment on this dog. In the following experiments the effect of quiet breathing decreases, perhaps due to some secretion formed in the lobe during experimentation. The effect of a one-minute period of normal breathing, preceding the other attempts at re-expansion, has been used in the subsequent experiments (Fig. 4, *B*, *C*, and *D* between signals *1* and *2*) as a standard for comparison, since it is an indication of the condition of the lobe.

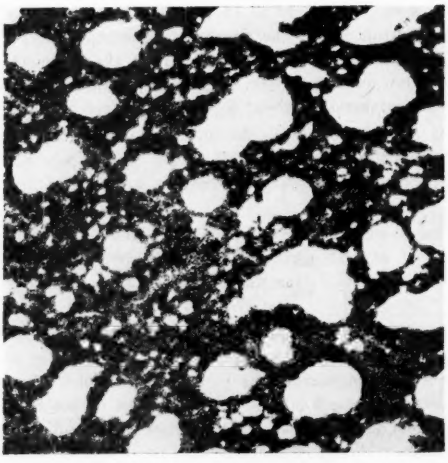

Fig. 3.—Incomplete atelectasis. Magnification ×65.

In Fig. 4, *B* between signals *2* and *3*, the dog was made to breathe 15 per cent carbon dioxide in air. The resulting hypercapnic hyperpnea is shown both by the tidal air curve at the top and by the pleural pressure curve at the bottom of the record. It is remarkable that the lobe's expiratory level from signal *2* on seemed to decrease, in spite of the hyperventilation. Actually the total volume of the system was increased by gas exchange in the lobe during the re-expansion period. This factor will be considered fully later in our report.

In Fig. 4, *C*, instead of carbon dioxide, the animal was given a mixture of 6 per cent oxygen in nitrogen. The resulting hypoxic hyperpnea differs from the hypercapnic hyperpnea of the preceding experiment (4, *B*) in that the increase in tidal air and pleural pressure excursions was less pronounced. The rate of breathing, however, increased from 20 to 33 against a rise from 22 to 27 per minute during the inhalation of carbon dioxide. Furthermore it may be observed that the pleural pressure mainly tended to increase in the inspiratory direction whereas in hypercapnic hyperpnea the expiratory increase was also very pronounced. These differences will be related to the different effect of both types of hyperpnea. The rise of the expiratory level of the atelectatic lobe

(middle curve) suggests a degree of re-expansion far exceeding that in experiment 4, *B*. Here too, however, the possibility that the gas exchange influenced the apparent result should be kept in mind.

In the experiment, shown in Fig. 4, *D* inspiration was obstructed at signal *2* by turning stopcock *7* (Fig. 2). The tidal air record was suddenly interrupted and the deflections of the pleural pressure record became strongly negative, corresponding with the inspiratory efforts of the animal. The atelectatic lobe itself, which was not affected by the obstruction, was free to expand. It was subjected to these extending forces and readily expanded to a very high level. A real overstretching of this lobe was suggested by the fall in its air

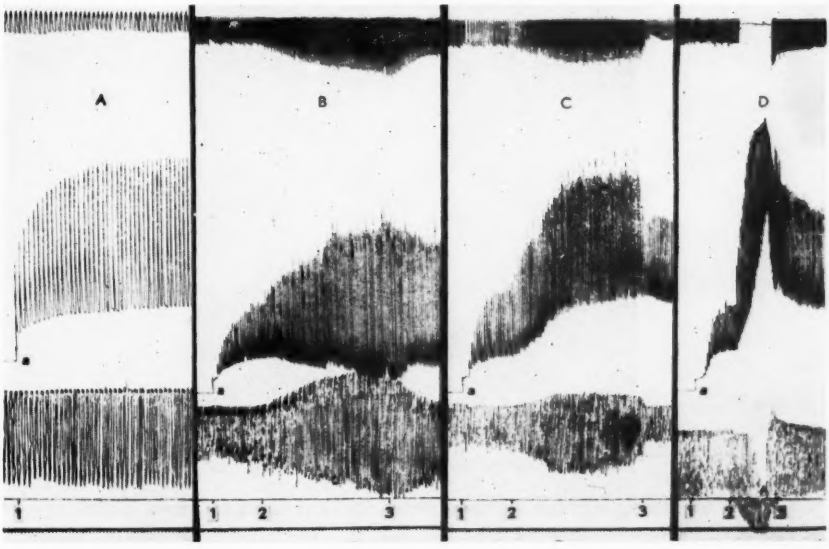

Fig. 4.—Re-expansion of the incompletely atelectatic lobe. Upper curve: tidal air of nonatelectatic sections. Middle curve: volume of the atelectatic lobe (inspiration upward). Lower curve: pleural pressure (inspiration downward). Signal *1*: connection of lobe with spirometer. Time: 4 seconds. *A*, dog breathing air; *B*, air, (*2*) 15 per cent carbon dioxide, (*3*) air; *C*, air, (*2*) 6 per cent oxygen, (*3*) air; *D*, air, (*2* to *3*) inspiratory obstruction.

content at signal *3* when normal breathing was restored. But even so the remaining volume corresponded to full expansion. In this instance (4, *D*) 31 ml. of gas could be removed after the re-expansion against 32 ml. at the beginning of the experiment. The result of the short-lasting experiments with obstructed breathing was not likely to be appreciably influenced by the gas exchange in the lobe.

B. Complete Atelectasis.—The occurrence of a complete resorption atelectasis after the procedure, previously described, was proved by microscopic examination (Fig. 5). An example of these experiments is shown in Fig. 6. In contrast to the usual procedure, here the various treatments were applied in succession without renewal of the state of complete atelectasis.

After the twenty-minute period for the resorption of the oxygen contained in the deflated left inferior lobe, connection was made with the spirometer at signal *1*. This is demonstrated by the sudden outflow of air (*a*) needed for restoring atmospheric pressure in the system. Normal quiet breathing (signal *1* to *2*) had little effect on the ventilatory movements and on the expiratory level of the completely atelectatic lobe. This remained true even when the period was prolonged to thirty or forty-five minutes. The small deflections which could be seen in the record of the spirometer were probably due to respiratory volume changes of the open air passages. Quiet breathing did not seem to exert any effect at all on the completely atelectatic lung tissue.

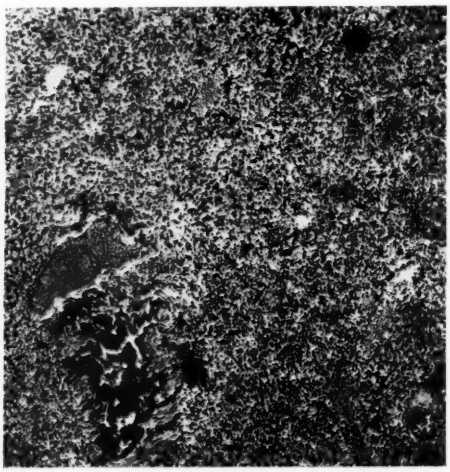

Fig. 5.—Complete atelectasis. Magnification ×65.

After breathing air for three minutes the animal was given a mixture of 10 per cent carbon dioxide in air at signal *2*. The record of pleural pressure showed the development of a mild hypercapnic hyperpnea causing a distinct, though slight, increase both of the ventilatory excursions and of the expiratory volume of the lobe. When, at signal *3*, the animal breathed atmospheric air for another three minutes, further expansion of the lobe was seen to cease as the hyperpnea disappeared.

Changing at signal *4* to a mixture of 6 per cent oxygen in nitrogen resulted in the development of a hypoxic hyperpnea as shown by the record of pleural pressure in which the rate of breathing increased from 12 to 29 per minute. Both the tidal volume and the expiratory level of the expanding lobe attained a height far in excess of that reached by any of the former procedures. When at signal *5* the hyperpnea was stopped by switching to atmospheric air, the lobe retained its level of expansion.

The results of these series of experiments on incomplete and complete atelectasis suggest that quiet breathing has only a little influence if any on re-expansion, whereas hyperpnea exerts a marked effect. The result of hypercapnic

hyperpnea is usually much less pronounced than that of hypoxic hyperpnea. In order to arrive at a definite conclusion, however, the volume changes of the lobe spirometer system by the gas exchange cannot be left out of the account.

C. The Gas Exchange.—Assuming that the amount of nitrogen in the system does not change, a quantitative evaluation of the gas exchange can be made; accordingly, the change in total volume of the lobe spirometer system can be calculated. Analysis of the well-mixed gas content of the system at the beginning and at the end of a re-expansion experiment provides two values pN_2 and $p'N_2$ for the concentration of nitrogen. In an experiment on complete atelectasis the initial volume of the lobe is zero, and as the volume of the spirometer-system and its connections can be determined, the total initial volume, V, of the entire

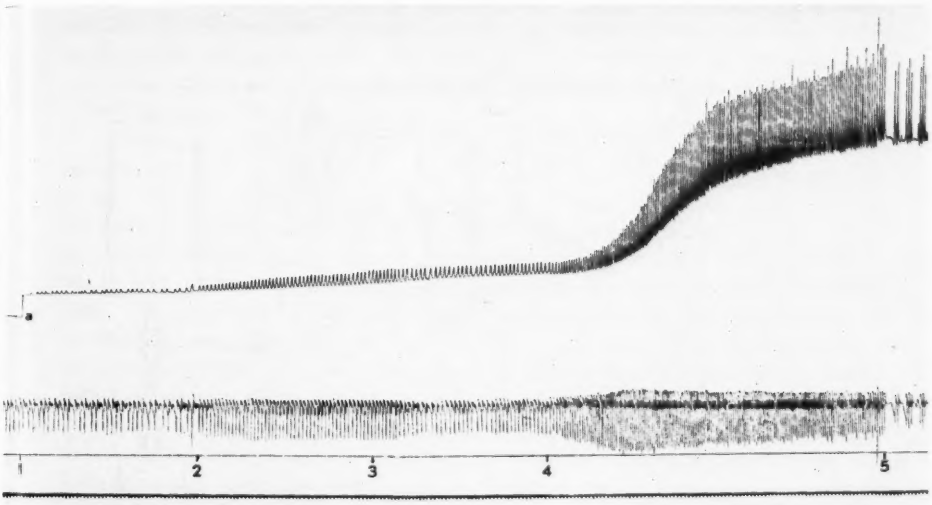

Fig. 6.—Re-expansion of the completely atelectatic lobe. Upper curve: volume of the atelectatic lobe (inspiration upward). Lower curve: pleural pressure (inspiration downward). Signal *1:* connection of lobe with spirometer, dog breathing air. Signal *2:* 10 per cent carbon dioxide. Signal *3:* air. Signal *4:* 6 per cent oxygen. Signal *5:* air. Time: 4 seconds.

system is known. The change in total volume during the experiment can be calculated according to the equation: $V - V' = V\ (1 - \frac{p\,N_2}{p'N_2})$, where V′ is the total volume of the system at the end of re-expansion. This difference can be applied as a correction to the apparent re-expansion, measured from the volume change of the spirometer. The initial pN_2 in the lobe system was installed in such a way as to be close to the expected value of the final $p'N_2$, in order to keep the correction as small as possible. The actual exchange of oxygen and carbon dioxide can be determined in a similar way by using the gas analytic data.

The rearrangement of the apparatus is illustrated schematically in Fig. 7. At the start of the experiment oxygen was given both to the lungs as a whole and

to the experimental lobe from a bag, which could be connected to stopcock *7*, by removing clamp *4*. The pump, *P*, caused a continuous flow of oxygen to pass through the inner tube inserted in the catheter, *1*, and to leave through tube *8* when clamps were applied at *3* and *6*. After five minutes the pump was stopped and the two systems were separated by replacing clamp *4*. While the remaining parts of the lungs still were breathing oxygen, the left inferior lobe was emptied in the usual way after clamping at *2*. During the twenty minutes needed for the development of a complete resorption atelectasis first the system between *2* and *6* was thoroughly washed out for five minutes with nitrogen entering at *3* and leaving at *8*. Bag *A*, after being emptied completely by raising bottle *B*, was then filled with a known volume (300 ml.) of nitrogen, which could be recorded on the spirometer by turning the three-way cock *9*.

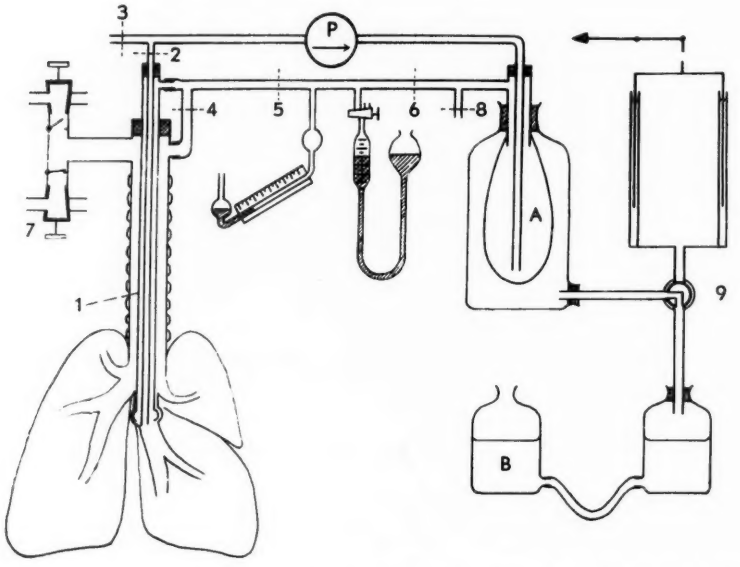

Fig. 7.—Apparatus for evaluating gas exchange during the re-expansion (description in article).

This completed, *9* was reset to its original position, clamps were placed at *3*, *5*, and *8*, and clamp *6* was removed. The pressure in bag *A* and associated tubing was now brought down to −4 cm. mercury by lowering water-bottle *B*. Since the same pressure had been maintained in the meantime in the catheter and in the lobe, mixing of the gases in the lobe system by pump *P* could be started after removing clamps *2* and *5*. At this time the oxygen, being given to the rest of the lungs, was replaced by air. After five minutes, *2* and *5* were closed again and atmospheric pressure in bag *A* was re-established by raising bottle *B*. After connecting the system with the spirometer by turning stopcock *9*, a sample for gas analysis could be drawn at *3*. Immediately the attempt at

TABLE I. GAS CONTENT (ML.) OF RE-EXPANDING LOBE AT END OF EXPIRATION OBTAINED WHILE BREATHING AIR

DURATION	APPARENT VOLUME	CORRECTION FOR GAS EXCHANGE	CORRECTED VOLUME
3 min.	−5	+6	+1
15 min.	+15	+9	+24
30 min.	+11	+11	+22
45 min.	+20	+6	+26

re-expansion was started by removing clamps *2* and *5* and eventually by administering a gas mixture at *7*. Meanwhile the pump, *P*, was running to assure thorough mixing. Three minutes afterward a second sample was drawn at *3*.

The corrected figure obtained for re-expansion usually compared well with the result of the following direct measurement. After sacrificing the animal at the end of a re-expansion, the isolated lobe was weighed in air and under water to determine its gas content. The lobe remained connected to the spirometer until the ligation of the bronchus, so that corrections could be applied for any volume change during the autopsy.

The experiments on the effect of quiet breathing and of hyperpnea by carbon dioxide and lack of oxygen were repeated with the previously mentioned technique. In the experiments on the effect of normal breathing, room air was presented to the nonatelectatic parts of the lungs for periods varying from three to forty-five minutes. In one of these experiments recovery periods of 3, 15, 30, and 45 minutes have been applied successively in order to obtain comparable data. The apparent results, read from the spirometer record and those corrected for gas exchange, are given in Table I. The positive correction corresponds to an increase in total volume of the system by carbon dioxide entering at a higher rate than oxygen disappearing.

The corrected results show that in this experiment the effect of normal breathing on re-expansion is greater than might be expected judging by our former results. Still an extension of the recovery period beyond fifteen minutes apparently does not have any appreciable effect. In relation to the effect of the more drastic procedures to be described only part of the lobe seems to be affected by normal breathing.

Table II shows the results of one of the experiments on hyperpnea by excess of carbon dioxide and by lack of oxygen.

TABLE II. GAS CONTENT (ML.) OF RE-EXPANDING LOBE AT END OF EXPIRATION AFTER 3 MINUTES OF NORMAL BREATHING, HYPERCAPNIC OR HYPOXIC HYPERPNEA

INSPIRATORY GAS	APPARENT VOLUME	CORRECTION FOR GAS EXCHANGE	CORRECTED VOLUME
Air	+37	+12	+49
10 per cent carbon dioxide	+25	+41	+66
5 per cent oxygen	+120	−35	+85

As might be expected the positive correction applied to the results was obtained again when breathing air or 10 per cent carbon dioxide. When, however, the animal was hypoxic, oxygen was eagerly taken up by the blood per-

fusing the expanding lobe which was filling with gas from the spirometer. Since the uptake of oxygen exceeded the elimination of carbon dioxide, a decrease of volume and accordingly a negative correction resulted.

Although the absolute quantities varied a good deal in individual cases, depending also upon the condition of the lobe, the data represented in Table II give a fair idea of the average results obtained in all similar experiments. Quiet breathing effected some expansion of the atelectatic lobe; the effect of hypercapnic hyperpnea is markedly greater, but the results of hypoxic hyperpnea are still appreciably better.

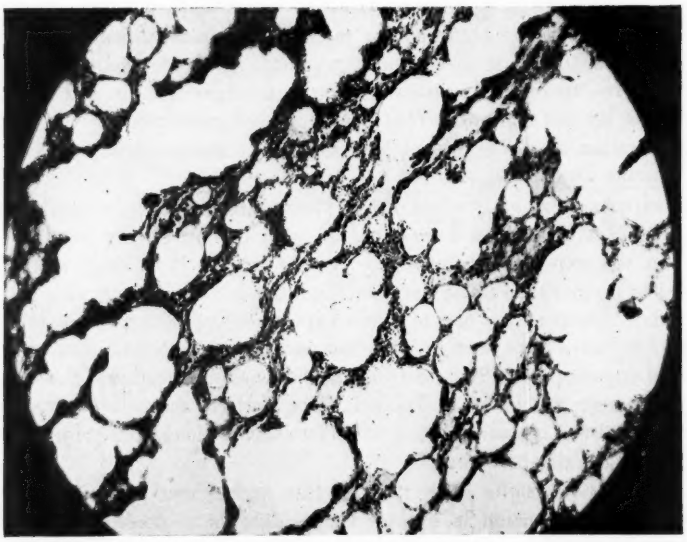

Fig. 8.—Completely atelectatic lobe re-expanded by hypoxic hyperpnea. Magnification ×65.

In all attempts at restoration, the re-expansion was found to spread rather irregularly over the lobe. Even after gradual re-expansion many atelectatic foci could be observed (Fig. 8) which commonly were dispersed over the whole lobe.

DISCUSSION

The conditions for re-expansion in our cases of freshly established uncomplicated atelectasis are probably different from those existing in clinical cases. Still a study of the relative efficacy of the various procedures for obtaining re-expansion may provide a useful experimental basis for further clinical trials. Moreover our experiments give some insight into the physiologic factors relating to the occurrence of local atelectatic parts in the lungs.

The most effective method for attaining re-expansion proved to be the inspiratory obstruction of the nonatelectatic parts of the lungs. The inspiratory efforts of the thorax, which assumed a maximal expiratory position, expiration being unobstructed, produced maximal negative deflections of pleural pressure.

Only the catheterized unobstructed atelectatic lobe could yield to this forceful pull and expanded within a short time (Fig. 4, *D*) to a volume, far in excess of the normal one. This was observed from the abrupt decrease in volume of the re-expanded lobe after removal of the inspiratory obstruction.

Instead of an outside negative pressure an inside positive pressure can be applied to the atelectatic lobe only. A pressure of +10 cm. of water in the catheterized lobe during normal breathing restored nearly normal air content, but part of the air restoration is due to an overdistention of open alveoli. For clinical purposes, however, catheterization of an atelectatic lobe is rather unfeasible and the overstretching may be dangerous.

Positive tracheal pressure does not set up a pressure gradient tending to expand an atelectatic lobe because the other surrounding lobes are subjected to the same pressure. It could only have an effect by increasing the total volume of the thorax, thereby increasing the tension in the lung structure as a whole. In isolated lungs a gradually increasing pressure, such as used by Lindskog and Bradshaw, will first inflate the normal parts which can extend freely until their stretch combined with the increasing pressure begins to affect the adjacent collapsed parts. At the end of inflation the total volume of the re-expanded lung exceeds the inspiratory volume of the thorax. Therefore an atelectatic lobe in situ cannot be reinflated like an atelectatic section in an isolated lung by a positive tracheal pressure. The lung cannot extend freely and the applied pressure is antagonized to a large extent by the tension of the chest wall.

When the lungs however, instead of being passively inflated by positive pressure, are engaged in active inspirations during hyperpnea, a re-expansion of atelectatic parts results. In comparison to hypercapnic hyperpnea the hypoxic type of hyperpnea commonly proved to be more efficient in our experiments, even when the tidal air excursions were more increased during carbon dioxide breathing than during hypoxia (Fig. 4). The excursions of the pleural pressure were more predominantly increased into the negative direction and the rate of breathing was much faster during hypoxic hyperpnea. In the experiments reproduced in Fig. 4, *B* and *C* the respiratory frequency rose from 22 to 27 per minute in hypercapnic and from 20 to 33 in hypoxic hyperpnea. The more rapid insipration during hypoxia caused greater negative excursions of the dynamic pleural pressure. These fast excursions were not accurately recorded by our rather slow recording system since a water manometer had to be placed between the thoracic balloon and the recording capsule. The balloon, moreover, was installed at the costal side, whereas the greatest pressure variations might be expected at the diaphragmatic face of the lungs. The strongly negative variations of dynamic pleural pressure reflected the considerable tensile forces which existed during the rapid inspirations throughout the viscous elastic structure of the whole lung and to which the atelectatic parts were also subjected. At the same time the pressure in the surrounding patent air spaces was minimal corresponding to maximal inspiratory flow. The direction of stretch in the lung fibers could act in a way as to tear apart the walls of collapsed air spaces so that the air could penetrate into them. Such a favorable direction of forces could be expected especially where the fibers diverged as was the case at the

border of a collapsed and a patent part of the lung tissue. In this connection the possibility of a collateral admission of air into the alveolar spaces by the same mechanism as that existing in collateral ventilation (Baarsma, Dirken and Huizinga, 1947) should be considered.

We have tried without success in some tentative experiments to ascertain the influence of surface tension on re-expansion by administering aerosols of surface active substances prior to the inducement of atelectasis. Adhesion by bronchial secretion may serve better to explain differences in re-expansibility and the decline of re-expansion during a prolonged series of experiments.

SUMMARY

In dogs the effect of different types of ventilation on the re-expansion of the incompletely and of the completely atelectatic left inferior lobe has been studied by means of a special catheter introduced into the corresponding bronchus. The types of ventilation were: normal spontaneous breathing, hypercapnic and hypoxic hyperpnea, and inspiratory obstruction of the normal lobes. The latter procedure proved to be the most efficient one but may cause overstretching of the lobe. The results of the hypoxic hyperpnea were markedly better than those of the other two procedures, presumably because of the increased dynamic pleural pressure caused by more rapid breathing.

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MALIGNANT DISEASE IN ASSOCIATION WITH HIATUS HERNIA AND THORACIC STOMACH

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THE account by Pack, Butler, and Katz[1] of two cases of adenocarcinoma of the stomach, in which the stomach was lying in an intrathoracic situation, prompts the brief report of the following cases where similar circumstances existed.

The frequency of the association had made us wonder whether it was of special significance, but we decided that a larger number of cases were required. The individual case reports included in this article were encountered among some seventy patients with hiatus hernia which were treated surgically. In addition we have encountered one case of carcinoma of the pylorus in a patient with a troublesome hiatus hernia, but the cancer lay in the abdominal part of the stomach.

CASE REPORTS

CASE 1.—This was an example of adenocarcinoma of the esophagus associated with hiatus hernia of the stomach. Mrs. C. W., 70 years old, presented a short history of dysphagia, retrosternal pain, regurgitation, and loss of weight. The lower end of the esophagus was seen to be narrowed by a growth, and a hiatus hernia, about 5 cm. in length, was seen above the diaphragm. At exploration a bulky growth was found extending from the apex of the herniated stomach to the aortic arch. Resection was carried out, and an esophagogastrostomy was performed above the aortic arch. All histologic studies of the growth reported moderately differentiated adenocarcinoma of the esophagus appearing to arise in the esophageal glands.

The patient, who was in poor general condition, did not do well and died soon after the operation. There was no history available to indicate whether there had been a long or short period of regurgitation and esophagitis before the discovery of the tumor.

CASE 2.—This case presented an undifferentiated adenocarcinoma of the stomach situated at the level of the hiatus, in association with the hiatus hernia. Mr. H. G., 72 years old, presented a three months' history of dysphagia, epigastric pain, and loss of weight. Radiologically a moderate-sized hiatus hernia of the sliding type and a segment of upper stomach narrowed by growth were seen. On esophagoscopy the esophagus seemed normal, gastric mucosa was seen, but no growth was recognized. On exploration a bulky hernia 9 cm. high was found; in the hiatus, which was 6 cm. in diameter, the upper edge of a gastric growth was felt; the remainder lay below the diaphragm. The diaphragm was opened, resection carried out, and repair made by esophagogastrostomy. Only a few small hard glands were encountered. The growth was a flat one encircling the upper stomach "in the grip of" the hiatus. Progress was good until the seventh postoperative day when leakage occurred, and in spite of resuture the patient died a few days later. Histologically the growth was an undifferentiated carcinoma, with invasion of at least one node.

CASE 3.—This is an example of fibrosarcoma of the lower esophagus in association with hiatus hernia. Mr. J. D., 63 years old, was hospitalized for a possible tumor of the lower end of the esophagus. For some months he had experienced pain beneath the lower end of the sternum, some dysphagia, and regurgitation, but he was not markedly reduced in condition. A previous x-ray examination had suggested a simple tumor of the lower end of

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Received for publication Nov. 13, 1952.

the gullet but these films could never be traced. On admission he was re-examined by fluoroscopy; a large sliding hiatus hernia 5 cm. high was seen, and no filling defect in the esophagus was found. Similarly on esophagoscopy, no tumor nor evidence of esophagitis was found. At the operation in May, 1951, for repair of the hernia by the transthoracic route, no tumor was felt in the walls of stomach or gullet, although "both parts felt a little on the thick side." The intestine was not opened; the hernia was tucked down, and the size of the hiatus reduced by silk stitches. Before discharge, fluoroscopy was repeated. The esophagus appeared normal in both the erect and Trendelenburg positions. There was no evidence of hernia. At this stage the patient's swallowing was good, and he was free of symptoms.

He was readmitted eleven months after the operation with a four weeks' history of pain and dysphagia. On fluoroscopy a large filling defect was seen in the lower third of the esophagus over which barium trickled. An impacted mass of food was suspected. On esophagoscopy a firm whitish mass was seen, one inch long on the right wall of the lower end of the esophagus. Biopsy was made. Radical resection of the lower gullet, upper stomach, spleen, part of pancreas, and adjacent tissues was performed, and esophagogastrostomy below the aortic arch restored the continuity. No glands were palpated or other metastases found. Histologic studies of the growth established the diagnosis of fibrosarcoma.

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A DOUBLE LUMEN CATHETER FOR BRONCHOSPIROMETRY*

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EXPERIENCE with the various types of bronchial catheter, the Zavod, the Gebauer, and more recently the Carlens, has shown that the latter is the most useful of these double lumen instruments for investigation of separate pulmonary function. However, it was found that even the Carlens catheter had certain disadvantages, and the catheter described here has some minor but important modifications based upon the Carlens double lumen model. The principles involved are the same, and the over-all measurement and measurement of the internal lumina are the same as for the Carlens catheter, that is, the cross-section area of lumina is about 39 sq. mm. in the large size (male) and 25 sq. mm. in the small size (female). The outer diameter is 13 to 14 mm. in the large size and 11 to 12 mm. in the small one.

The modifications are:

1. A wire spiral is incorporated in the whole length of the catheter. This spiral is in the wall of a latex tube and passes down to the tip of the tube used for the left stem bronchus.

2. There is a malleable strip at the level of the opening for the right stem bronchus, and this passes some distance into the tube for the left stem bronchus.

3. The hook for engaging the carina, instead of being made of semirigid rubber, is made of a thin watch spring covered in latex. This hook when passing through the cords is held down by a sleeve, distal to the balloon used for occluding the left stem bronchus.

4. Radiopaque material is incorporated in the tube at the level of the two distal balloons as well as at the actual tip of the tube passing into the left stem bronchus.

The advantages claimed for this catheter are:

1. Being made of latex it is more malleable than the semirigid rubber one of Carlens,[1] and since a wire spiral is used to form the wall of the catheter, kinking is minimized. The wire spiral makes the catheter easy to handle, and there is no need for a metal introducer.

Should there be any gross scoliosis or other abnormality in the patient which will lead to a deviation of the trachea, it will be found that this catheter can be passed more easily and with less discomfort to the patient than the Carlens catheter.

2. The malleable strip enables the lower part of the catheter to be bent to a convenient angle for passing through the cords under direct vision with the aid of a suitable laryngoscope. When the tip of the catheter is through the

Received for publication Nov. 13, 1952.

*Obtainable from Talley Anaesthetic Equipment Ltd., 54, Dorset Street, Baker Street, London, W.1.

**Consultant Physician: Chest Clinic, Camberwell, London, S.E. 5.

cords the catheter is then turned through a right angle and passed further down the trachea. The tip of the catheter will tend to press against the left-hand wall of the trachea and will so pass more readily into the left stem bronchus.

3. The hook will easily engage the carina if the distal balloon is temporarily inflated once the tip of the catheter has been passed down through the cords. The sleeve retaining the hook will drop back into place and not interfere in any way with distention of the distal balloon. Dusting with French chalk is advisable to lubricate the surfaces.

Fig. 1.

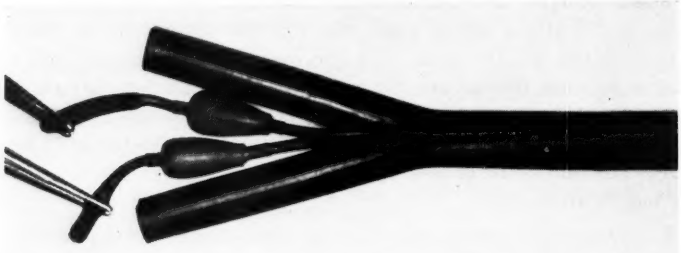

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 1.—The proximal balloons for inflation and the latex-covered metal spiral.
Fig. 2.—The two distal balloons and the malleable strip. Note flexibility of catheter.
Fig. 3.—Hook held down by sleeve.
Fig. 4.—Both balloons inflated and hook released from sleeve.

4. The radiopaque bands at the distal balloons as well as the tip, the wire spiral, and the clock spring in the hook are of considerable assistance when identifying the position of the catheter on fluoroscopy.

5. As the cuffs and sleeve are made of the same material as the catheter itself, namely, latex, it is very easy to effect any repair to these important components should they become broken through accidental overdistention of the balloon or tearing in any way when sterilizing. Sterilization can be effected by boiling.

6. Air flow resistance tests show that this catheter has the lowest resistance of any make of double lumen catheter so far tested.

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MAXIMUM BREATHING CAPACITY AND THE SALINE INFUSION TEST

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WITH the widening scope of thoracic surgery there has been an increased effort toward finding a simple test or group of tests to adequately evaluate the respiratory and cardiac reserves of the preoperative patient. Although there are numerous procedures now available for studying the physiologic reserves of patients with cardiorespiratory diseases, most of these require special laboratory equipment and highly trained personnel. To date the only procedure recommended by the Sub-Committee on Pulmonary Function Tests of the American Trudeau Society as minimal requirements beyond the conventional history, physical examination, fluoroscopic examination, and inspiratory and expiratory chest roentgenograms is the determination of the maximum breathing capacity.[1]

To perform the maximum breathing capacity test a minimum of equipment is required. Considerable training of the patient is not necessary, and according to Gray and his associates[2] maximum values are usually obtained after one practice effort. However, there are few data concerning the variability in maximum breathing capacity in healthy individuals day by day over a period of months. According to Comroe[3] normal figures obtained in different laboratories vary by as much as 32 per cent according to the type of apparatus used and the resistance it offers to breathing. Because of the large standard deviation a healthy person may deviate by as much as 25 to 35 per cent of the mean group value; consequently, reduction in the maximum breathing capacity must be large to be significant.

Caughy[4] in 1935 and Richards and associates[5] in 1937 recommended a saline infusion test for evaluating a patient's cardiac reserve. This procedure is relatively easy to perform while the patient is on the ward. It does not require special equipment.

Because of the relative simplicity of the maximum breathing capacity test and the saline infusion test of Caughy, these were selected to be routine preoperative procedures on all patients on the thoracic surgical service. The results of these tests are reported in this article.

METHODS

The maximum breathing capacity test was performed in the cardiopulmonary function laboratory by trained technicians. The test was carried out with the patient in a sitting position using a specially designed high velocity—low resistance valve. The test was performed for a period of thirty seconds, allowing the patient to choose his own frequency and tidal volume.

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Received for publication Nov. 17, 1952.

The procedure was always repeated following a rest period of twenty minutes. Duplicate values within 5 liters of the maximum were required. The results were expressed in liters per minute.

The saline infusion test was carried out as outlined by Caughy. An infusion of normal saline solution was started in an arm vein while the patient was lying in bed. The level of the chosen vein was so adjusted that it approximated the level of the right auricle. Pulse, blood pressure, venous pressure, circulation time, respirations, vital capacity, and auscultation of the heart and lung fields were recorded. The saline solution was allowed to infuse at the rate of 200 c.c. per five minutes. Pulse, blood pressure, venous pressure, and respirations were observed and recorded every five minutes. At the end of thirty minutes the infusion was discontinued, the vital capacity and circulation time were again measured and auscultation of the chest was performed.

Electrocardiograms also were taken preoperatively on all the patients.

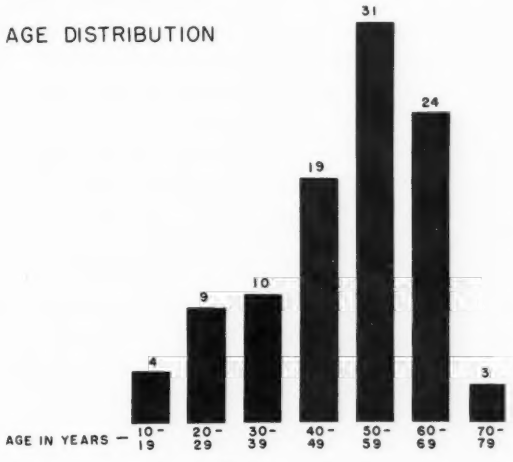

Fig. 1.

MATERIALS

One hundred consecutive patients admitted to the thoracic surgical service, on whom "open chest" operations were performed, are the subject of this

TABLE I

DIAGNOSIS	NUMBER OF CASES
Carcinoma, bronchus	34
Bronchiectasis	17
Pulmonary tuberculosis	9
Mediastinal tumors	6
Carcinoma, esophagus	5
Lung cyst	4
Lung abscess	3
Nontuberculous empyema	3
Spontaneous pneumothorax	3
Esophageal stricture	3
Diaphragmatic hernia	3
Miscellaneous	10
Total	100

study. The only cases excluded were the surgical emergencies. The age range was from 16 to 74 years with a distribution as illustrated in Fig. 1. The most frequent diagnosis (Table I) was carcinoma of the bronchus which accounted for 34 per cent of the cases. The most common operative procedures were exploratory thoracotomy, lobectomy, and pneumonectomy. These accounted for 30 per cent, 26 per cent, and 19 per cent of the operations, respectively (Table II).

TABLE II

OPERATIVE PROCEDURES	NUMBER OF CASES
Exploratory thoracotomy	30
Lobectomy	26
Pneumonectomy	19
Decortication	7
Excision mediastinal tumor	5
Esophagogastrostomy	5
Repair diaphragmatic hernia	2
Miscellaneous	6
Total	100

RESULTS

In evaluating tests such as the maximum breathing capacity and the saline infusion tests, it becomes paramount to consider each case separately regarding age, diagnosis, degree of pulmonary emphysema, sputum, operative procedure (especially the amount of lung tissue removed, if any), etc. Although all of these factors were considered in evaluating each patient for surgery and also in drawing conclusions as to the worth of these two tests, only the collective results can be considered in this paper.

TABLE III. DISTRIBUTION OF M. B. C. VALUES IN ONE HUNDRED CONSECUTIVE OPEN CHEST CASES

M. B. C.	NO. CASES
To - 49 L/m.	12
50 - 79 L/m.	50
80 L/m. or more	38
Total	100
% M. B. C.	NO. CASES
To - 49%	8
50 - 79%	44
80 - 100+%	48
Total	100

Table III shows the maximum breathing capacity values which have been arbitrarily divided into three groups: up to 49 liters per minute, 50 to 79 liters per minute, and 80 liters per minute and up. Table III also shows the distribution of the patients when the percentage of predicted normal values for maximum breathing capacity are similarly grouped (predicted normal values are based on the formulas of Baldwin and her co-workers[6]). Only 8 per cent of the patients had maximum breathing capacities of 49 per cent or less of predicted normal. In absolute values 12 per cent of the patients had maximum breathing capacities of 49 liters per minute or less.

Table IV records the pertinent data on each patient whose maximum breathing capacity was either 49 liters per minute or less or whose maximum

TABLE IV. PATIENTS WITH M. B. C., 49 L./M. OR PER CENT M. B. C., 49 PER CENT

PT.	AGE	DIAGNOSIS	OPERATION	M. B. C. L./m.	M. B. C. %	SALINE INFUSION	P. O. DAYS NASAL O_2	P. O. HOSP. DAYS	DYSPNEA 2-3 MONTHS P. O.
H. C.	60	Nontbc. empyema and B-P fistula	Decortication, left	37	48	Normal	1	13	Mild exercise
A. L.	55	Metastatic Ca., sternum	Excision of sternum	41	50	Normal	1	24	Moderate exercise
G. E.	64	Ca., esophagus	Exp. thoracotomy, rt. gastrostomy	30	32	Normal	2	12	At rest
E. W.	42	Lung cysts	Pneumonectomy, left	41	38	Normal	3	14	At rest
M. H.	64	Ca., bronchus	Exp. thoracotomy, rt.	48	50	Normal	1	10	Mild exercise
R. B.	57	Tbc. empyema	Open drainage and thoracoplasty	49	49	Abnormal	1	To san.	At rest
S. W.	59	Ca., bronchus	Exp. thoracotomy, rt.	39	42	Normal	3	4	Expired 4 days P. O.
F. M.	47	Bronchiectasis	Lobectomy, L.L.L.	42	58	Normal	1	13	None
A. B.	64	Fibrosarcoma of mediastinum	Exp. thoracotomy, rt.	33	47	Normal	1	10	Mild exercise
J. R.	74	Ca., esophagus	Esophagogastrostomy	30	42	Normal	1	12	Mild exercise
S. K.	50	Asthma	Plexectomy, left	35	52	Normal	1	20	None
F. C.	58	Ca., bronchus	Exp. thoracotomy, rt.	48	55	Normal	1	10	Mild exercise
E. F.	24	Tbc. empyema and B-P fistula	Decortication, rt.	65	44	Normal	1	44	None

breathing capacity was 49 per cent or less of the predicted normal. In this group there was only one case in which the saline infusion test was considered abnormal, but nine of these cases had what was recognized preoperatively as clinical emphysema. Postoperative dyspnea at rest or on mild exercise was present in a high incident. Only three patients, however, were on nasal oxygen postoperatively longer than one day. The most interesting observation is that only two patients, E. W. and F. M., had any lung tissue removed. Patient E. W., who had a left pneumonectomy for cystic disease, had a preoperative bronchospirometry which showed his left lung to be contributing only 8 per cent of his minute ventilation and oxygen consumption. Patient F. M. was one of the few subjects who had difficulty in understanding

TABLE V. PATIENTS REQUIRING NASAL OXYGEN IN EXCESS OF ONE DAY*

NAME	AGE	DIAGNOSIS	OPERATION	M. B. C. LITERS	M. B. C. (%)	P. O. DAYS NASAL O_2
F. D.	65	Ca., bronchus	Pneumonectomy, rt.	101	(98)	2
R. V.	50	Ca., bronchus	Pneumonectomy, left	132	(123)	2
G. E.	64	Ca., esophagus	Exp. thoracotomy, rt. gastrostomy	30	(32)	2
C. C.	69	Chronic pneumonitis	Lobectomy, rt.	77	(94)	2
L. S.	43	Pulmonary tbc.	Lobectomy, left	65	(85)	2
S. W.	69	Ca., bronchus	Exp. thoracotomy, rt. Expired 4th P. O. day. Coronary thrombosis	39	(42)	3
J. G.	67	Ca., bronchus	Lobectomy, rt.	51	(58)	6
E. M.	67	Ca., bronchus	Pneumonectomy, left. Expired 7th P. O. day. Pneumonia	56	(67)	6

*All of these patients had normal electrocardiograms and normal saline infusion tests.

the maximum breathing capacity procedure, and he failed to give a maximum effort. In addition, his left lower lobe, which was removed at the time of surgery, was undoubtedly contributing little to his total ventilation.

Table V shows the group who required nasal oxygen for periods greater than one day. Of these patients all had normal preoperative saline infusion tests and electrocardiograms. In this group the M.B.C. (maximum breathing capacity) ranged from 32 per cent to 123 per cent of the predicted normal. There was considerable lung tissue removed in six of the eight cases; the remaining two cases had nonresectable carcinomas, one of the esophagus and one of the bronchus in patients 64 and 69 years of age, respectively.

TABLE VI. PATIENTS HAVING POSTOPERATIVE DYSPNEA

PT.	AGE	DIAGNOSIS	OPERATION	M. B. C. L./m.	M. B. C. %	P. O. DYSPNEA	SALINE INFUSION
G. E.	64	Ca., esophagus	Exp. thoracotomy, rt. gastrostomy	30	32	Rest	Normal
E. W.	42	Lung cysts	Pneumonectomy, left	41	38	Rest	Normal
A. B.	64	Fibrosarcoma, mediastinum	Exp. thoracotomy, rt.	33	47	Mild exercise	Normal
H. C.	60	Nontbc. empyema	Decortication, left	37	48	Mild exercise	Normal
F. B.	54	Ca., bronchus	Pneumonectomy, left	60	53	Mild exercise	Abnormal
F. C.	58	Ca., bronchus	Exp. thoracotomy, rt.	48	55	Mild exercise	Normal
L. H.	67	Ca., bronchus	Pneumonectomy, rt.	50	58	Mild exercise	Abnormal
A. G.	41	Ca., bronchus	Exp. thoracotomy, rt.	77	60	Rest	Normal
J. F.	57	Ca., bronchus	Pneumonectomy, left	60	60	Mild exercise	Abnormal
G. B.	69	Ca., bronchus	Pneumonectomy, rt.	61	66	Mild exercise	Abnormal
G. T.	71	Ca., bronchus	Pneumonectomy, left	60	75	Mild exercise	Normal
R. B.	57	Pulmonary tuberculosis	Pneumonectomy, rt.	79	75	Rest	Normal
E. F.	50	Ca., bronchus	Pneumonectomy, left	90	78	Mild exercise	Normal
J. C.	38	Bronchiectasis	Pneumonectomy, rt.	89	94	Mild exercise	Normal
F. D.	65	Ca., bronchus	Pneumonectomy, rt.	101	98	Mild exercise	Normal
W. L.	28	Ca., bronchus	Exp. thoracotomy, rt.	125	109	Mild exercise	Normal
R. V.	50	Ca., bronchus	Pneumonectomy, left	132	123	Mild exercise	Normal
A. L.	55	Met. ca., sternum	Excision of sternum	41	50	Mild exercise	Normal
M. H.	64	Ca., bronchus	Exp. thoracotomy, rt.	48	50	Mild exercise	Normal
R. B.	57	Tbc. empyema	Open drainage and thoracoplasty. Post-pneumonectomy	49	49	Rest	Abnormal
J. R.	74	Ca., esophagus	Esophagogastrostomy	30	42	Mild exercise	Normal

There was a group of twenty-one patients who had dyspnea at rest or on mild exercise when observed two to three months postoperatively (Table VI). The preoperative M.B.C. ranged from 32 per cent to 123 per cent. In this group five patients had abnormal saline infusion tests, but of these only one had dyspnea at rest. None of these patients experienced any circulatory disturbances postoperatively. Thus it readily is seen that the level of preoperative maximum breathing capacity had no bearing on the dyspnea experienced postoperatively, and there is no correlation with the saline infusion test. However, in this group experiencing postoperative dyspnea, there were eleven patients who underwent pneumonectomies and six patients who had nonresectable cancers.

Of the eleven patients who had abnormal electrocardiograms, all had normal saline infusion tests. They did not require postoperative nasal oxygen

TABLE VII. PATIENTS WITH ABNORMAL ELECTROCARDIOGRAM*

NAME	AGE	DIAGNOSIS	OPERATION	ELECTROCARDIOGRAM	P. O. DAYS NASAL O_2
N. K.	54	Ca., bronchus	Exp. thoracotomy, rt.	Sinus arrhythmia rt. bundle br. block	1
P. S.	67	Ca., bronchus	Exp. thoracotomy, rt.	Premature ventricular contractions, myocardial damage	1
C. B.	65	Ca., bronchus	Exp. thoracotomy, left	Sinus tachycardia, myocardial damage	1
E. B.	54	Ca., bronchus	Exp. thoracotomy, rt.	1st degree a.v. block	1
W. O.	50	Ca., bronchus	Exp. thoracotomy, rt.	Auricular flutter varying block	1
C. S.	46	Spont. pntx.	Decortication, left	Myocardial damage	1
S. M.	30	Spont. pntx.	Decortication, left	Myocardial damage	1
E. F.	24	Tbc. empyema B-P fistula	Decortication, rt.	Myocardial damage	1
J. B.	34	Lung abscess	Lobectomy, rt.	Rt. bundle br. block	1
R. B.	57	Tuberculosis	Pneumonectomy, rt.	1st degree a.v. block	1
J. R.	74	Ca., esophagus	Esophagogastrostomy	Left axis deviation, left vent. hypertrophy	1

*All of these patients had normal saline infusion tests.

longer than one day, and none experienced significant circulatory disturbances postoperatively (Table VII). On the fourth postoperative day one patient who had normal preoperative electrocardiogram died of coronary artery thrombosis.

There were twelve patients who had abnormal saline infusion tests, but in each the electrocardiogram was within normal limits (Table VIII). Their maximum breathing capacities ranged from 49 per cent to 101 per cent; none required nasal oxygen longer than one day; and none experienced difficulty in the immediate postoperative period. Six patients in this group experienced dyspnea when observed two to three months postoperatively. Of these six, three had pneumonectomies, two had nonresectable bronchiogenic carcinomas, and one had tuberculous empyema and thoracoplasty.

TABLE VIII. PATIENTS WITH ABNORMAL SALINE INFUSION TEST*

PT.	AGE	DIAGNOSIS	OPERATION	M. B. C.		P. O. DAYS NASAL O_2	P. O. DYSPNEA
				L./m.	%		
J. D.	60	Mesothelioma, pleura	Exp. thoracotomy, rt.	64	69	1	None
R. F.	44	Pulmonary tuberculosis	Lobectomy, rt.	103	82	1	None
H. M.	65	Ca., bronchus	Exp. thoracotomy, left	68	65	1	Mild exercise
A. D.	49	Ca., bronchus	Pneumonectomy, left	112	92	1	None
F. B.	54	Ca., bronchus	Pneumonectomy, left	60	53	1	Mild exercise
J. F.	57	Ca., bronchus	Pneumonectomy, left	60	60	1	Mild exercise
G. B.	69	Ca., bronchus	Pneumonectomy, rt.	61	66	1	Mild exercise
F. E.	54	Ca., bronchus	Exp. thoracotomy, rt.	79	65	1	Mild exercise
R. B.	57	Tbc. empyema	Thoracoplasty and open drainage, rt.	49	49	1	At rest
G. S.	59	Fibrosarcoma, mediastinum	Exp. thoracotomy, left	65	81	1	None
M. M.	28	Bronchiectasis	Pneumonectomy, left	70	75	1	None
P. S.	58	Diaph. hernia	Thoracotomy, repair of hernia	73	101	1	None

*All of these patients had normal electrocardiograms.

CONCLUSIONS

In evaluating the ventilatory disability of the patient prior to an open chest operation the determination of the maximum breathing capacity proved a useful adjunct. Twenty of the twenty-one patients who experienced dyspnea at rest or on mild exercise, when examined two to three months postoperatively, had undergone a pneumonectomy or had a nonresectable cancer.

The saline infusion test and the electrocardiogram proved of little aid in preoperative evaluation in this group of cases. Every patient with an abnormal saline infusion test had a normal routine preoperative electrocardiogram, and every patient with an abnormal electrocardiogram had a normal saline infusion test. One patient, who died on the fourth postoperative day of coronary artery thrombosis, had both a normal electrocardiogram and normal saline infusion test preoperatively.

SUMMARY

1. Maximum breathing capacity tests, saline infusion tests, and electrocardiograms were performed preoperatively on 100 consecutive patients who were admitted to the thoracic surgical service and on whom open chest operations were performed.

2. These routine electrocardiograms and saline infusion tests were not helpful in the preoperative evaluation of this group of patients.

3. The maximum breathing capacity was very helpful in evaluating the degree of ventilatory disability in these patients.

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BRONCHO-SUBDIAPHRAGMATIC FISTULA

With A Report of Two Cases

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BEFORE the antibiotics were available broncho-subdiaphragmatic fistula was not an uncommon occurrence following subphrenic abscess. Guy and Oleck[1] state that "bronchial fistulas are reported to occur in about 10 to 12 per cent of all cases of subphrenic abscess." Head and Hudson[2] state that the incidence of this complication was so high that it was to be expected when the operation was delayed too long.

It is known[1] that suppurative lesions of the liver may drain into a bronchus after becoming adherent to the diaphragm in the absence of a true subphrenic abscess. Amebic and echinococcic cysts of the liver may eventually cause a bronchial fistula. Although collections of pus in the upper abdomen may frequently bore upward through the diaphragm, pus in the thorax rarely, if ever, extends downward into the abdomen because lymphatic drainage of the diaphragm is in a cephalad direction. Ochsner and DeBakey[3] stress the fact that thoracic complications are definitely attributable to late diagnosis of the intraperitoneal disease and to delay in institution of the proper treatment.

Head and Hudson[2] point out that the meagerness of thoracic findings on the chest roentgenogram in the presence of fever and copious expectoration is one of the most important diagnostic points in broncho-subdiaphragmatic fistula. After bronchiectasis has been ruled out by bronchography in such cases, and it is still not possible to explain the abundant expectoration, it is well to consider the possibility that the pus is coming from below the diaphragm. They also feel that in an acute unperforated subphrenic abscess exploratory aspiration is dangerous. They state that it is practically impossible to reach the pus without passing the needle through the free pleural cavity, and thus there is the danger of producing acute empyema.

Ochsner and DeBakey's extensive review of the literature revealed that the prognosis of subdiaphragmatic abscess with bronchial fistula is extremely poor. In their personal series[3] the mortality of those with thoracic complications was 50 per cent. Head and Hudson reported the case histories of three patients, all of whom recovered after proper drainage of the abscess. Head feels that the treatment of this serious complication should be the same as that for uncomplicated subphrenic abscess, namely, incision and drainage. In these cases he feels the pleura is usually adherent to the diaphragm and drainage can be instituted safely through the chest wall as a one-stage procedure.

I would like to report two cases of subphrenic abscess with bronchial fistula both of which were treated by drainage (one also had a right lower lobectomy).

From the Department of Surgery, Jefferson Hospital.
Received for publication Nov. 18, 1952.

CASE REPORTS

CASE 1.—Mr. M. W. W. was a 42-year-old man. He was admitted to the hospital on June 4, 1952. He stated that he had been entirely well until March 31, 1952. At that time he experienced lower abdominal pain which was not accompanied by nausea nor vomiting. He was operated on at another hospital, where he was told that he had an acutely inflamed appendix which was not removed but drained. He remained in that hospital for sixteen days. At the time of discharge the patient experienced some soreness in the upper abdomen along the rib margins and into the back. This soreness continued while he remained home for about one month. He then returned to work and was able to work intermittently for thirty days but still was conscious of the same soreness and discomfort in the upper abdomen. He had no fever, but the pain became increasingly severe.

Thirteen hours before admission to this hospital he began to cough for the first time. It was a dry, hacking, nonproductive cough. About one hour before admission he began to cough up clear mucoid material. Several hours after admission he felt a peculiar sensation in his right upper quadrant and right lower chest, and then began to cough up a large amount of foul tasting yellow sputum. The patient felt that this was coming from the right lower chest. He began to run a fever at this time.

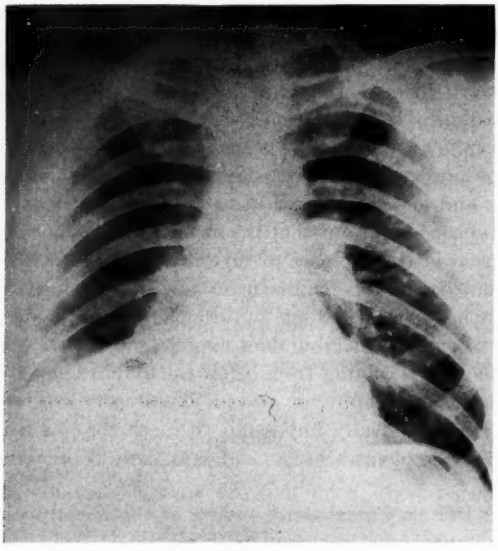

Fig. 1.—Mr. M. W. W., Case 1.

Physical examination revealed a well-developed and well-nourished man who was acutely ill. The patient's temperature was 102° F.; pulse was 108; respiration was 20. There was evidence of elevation and fixation of the right diaphragm. There was percussion tenderness over the right lower chest posteriorly. The lungs were essentially clear to auscultation except for the absence of breath sounds over the right lower chest posteriorly. Abdominal examination revealed some tenderness in the right upper quadrant but this was not marked. There were no masses, and there was no muscle spasm. The patient's temperature rose to 103° F. several hours after admission. Fluoroscopy revealed the right diaphragm to be fixed and elevated. Needle aspiration through the right tenth interspace in the posterior axillary line revealed thick creamy pus. In an attempt to further localize the abscess on the x-ray picture, 20 c.c. of air was injected. This immediately caused the patient to cough, and air could be heard rising in the chest. The sputum, which had already

been purulent, became bloody and purulent. It was felt that the patient definitely had a fistula between the subdiaphragmatic space and the right lung. He was taken to the operating room shortly thereafter and a subdiaphragmatic abscess was drained through the posterior route. The twelfth rib was resected and the abscess cavity was found to be in the right posterior superior space. The cavity was approximately the size of a small grapefruit. The material removed from the abscess was cultured and found to contain ß streptococcus. Three large Penrose drains were placed in the abscess cavity and were not completely removed until twelve days later. The patient made an essentially uneventful recovery following this operation and on June 12, 1952, an appendectomy was performed. The appendix at operation appeared to be subacutely inflamed. At the same time a small incisional hernia which had been present following McBurney drainage was repaired. The pathologic report on the appendix was subacute diffuse appendicitis. The patient did not expectorate any sputum after the subdiaphragmatic drainage. He made a good recovery from the appendectomy and was discharged apparently well on June 20, 1952.

Case 2.—Mr. R. L. was a 44-year-old arsenal worker. He was operated on in another hospital in April, 1951, for a ruptured appendix. He never felt entirely well after this operation but was able to return to work for five months between April, 1951, and December, 1951. In December, 1951, through a right upper quadrant incision, a subphrenic

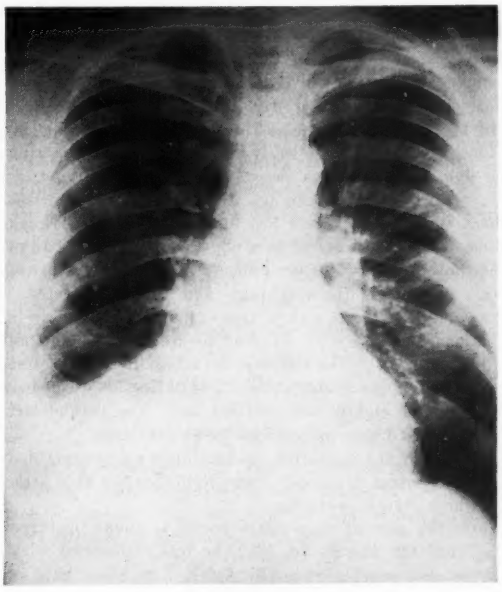

Fig. 2.—Mr. R. L., Case 2.

abscess was drained in the same hospital. While in the hospital he began to expectorate large amounts of bloody, purulent material. After leaving the hospital he continued to expectorate between one-half pint to one pint of bloody purulent material daily. Antibiotics diminished the amount of sputum, but never completely abolished it; whenever they were stopped the amount of sputum increased.

In April, 1952, the patient was referred to this hospital. At that time he was coughing up about six or eight ounces of pink or brown, and sometimes frankly bloody, thick sputum daily. The predominant organisms were: α, ß, and γ streptococci, *Diplococcus pneumoniae,* hemolytic and nonhemolytic *Staphylococcus aureus* and *Proteus morganii.* Smears, culture, and guinea pig inoculation were negative for tuberculosis.

Sensitivity studies showed the organisms to be more sensitive to Chloromycetin than any other antibiotic. He was given a two-week course of this drug. Following this he was given aerosol penicillin. On aerosol penicillin the sputum was reduced in amount but was absent only for several days. At that time he developed pain in the right upper quadrant of the abdomen and the right lower chest. He expectorated a large amount of foul smelling purulent sputum; this relieved the pain somewhat.

Past history revealed that the patient had had bronchial asthma during his entire life and had wheezed all the time. He had had an occasional cough with a small amount of sputum. He attributed the asthma to cold, dampness, and change of temperature. He had lost fourteen pounds since onset of the present illness. Physical examination revealed a well-developed and well-nourished white man in no acute distress. The patient's temperature was 98.6° F.; the pulse was 76; respiration was 18; blood pressure was 130/80. He had edentia but otherwise the head and neck were normal. Auscultation of the lungs revealed only an occasional râle in the right base. The abdomen was soft. There was a right upper quadrant scar and two right lower quadrant scars.

On April 14, 1952, a bronchogram was made, which revealed no bronchiectasis of either lower lobe. The patient was admitted to this hospital on May 17, 1952, and on May 19, 1952, exploration was made through a right thoracotomy incision. The eighth rib was resected. There were many dense adhesions between the visceral and parietal pleura. The right lower lobe was intimately agglutinated to the diaphragm which was considerably elevated. A No. 18-gauge needle was placed into this tented up portion of the diaphragm. About 10 to 15 c.c. of thick pinkish pus was obtained. The lung in this area was very densely adherent to the diaphragm and it was impossible to free it without cutting the lung. The lung was then dissected away from the diaphragm; it was felt there was a definite fistula between the subdiaphragmatic abscess and the right lower lobe. The mediastinum and the middle and upper lobes were well walled off by adhesions. There was practically no collapse of the upper and middle lobes with the chest open. The right lower lobe was dissected from the diaphragm. The patient was then found to be losing a great deal of air through the openings that had been made in the lower lobe by the dissection. Air was also being lost through the fistula. Because of the loss of air it was felt that the most expedient way of handling the situation was to perform a right lower lobectomy. The lobectomy was made rather difficult by the rather dense adhesions in the hilar region. An opening was made in the diaphragm and a finger inserted. A cavity about the size of an orange was felt. This was sucked free of pus. The opening in the diaphragm was left open to allow drainage into the well-walled-off pleural cavity. The patient's postoperative course was essentially uneventful. He was kept on constant chest suction, and penicillin was inserted into the suction tubes every day. One chest cathether was removed on the fifth day and the remaining one on the eighth postoperative day. The patient left the hospital on the tenth postoperative day; he had been ambulatory for several days.

About three weeks after the operation he developed an unexplained cough with a moderately large amount of sputum for about forty-eight hours. This attack subsided on self-prescribed and self-administered penicillin.

Some weeks later the patient once again began to cough up large amounts of brownish foul-smelling sputum. On August 20, 1952, he was readmitted with a provisional diagnosis of a recurrent broncho-subdiaphragmatic fistula. At about this same time an old McBurney incision that had been made at another hospital began to drain. On August 24, 1952, the anterior superior subdiaphragmatic space was explored through an upper right rectus incision. No pus was encountered. Then the drainage tract in the right lower quadrant was explored; the tract was found to go up into the posterior superior subdiaphragmatic space. This cavity felt about the size of an orange. Two large cigarette drains and a cathether were inserted. Penicillin was inserted into the catheter every eight hours. The drains were not entirely removed until the fourteenth day. He was discharged on September 11, 1952, free of drainage and cough. He has been well until the present time.

The pathologic report on the specimen removed at the first operation is as follows:

Gross.—The specimen consisted of the right lower lobe weighing 270 Gm. The diaphragmatic surface was scarred. It contained a number of adhesions. On the diaphrag-

matic surface near the hilum there was a raw area. Directly beneath this there was a scar in the lung tissue measuring approximately 4 cm. in diameter. There were several smaller bronchi running into this area and these were seen to contain purulent material. Upon pressure in this region several small purulent channels could be noted. There was very little bronchiectasis. There was considerable atelectasis.

Microscopic.—Sections of the lung showed the presence of a marked acute and chronic inflammatory process. There was considerable fibrosis. Some areas were well healed and hyalinized; some was still quite active and infiltrated with neutrophils. There were several sinus tracts running through the scar tissue. These were lined by granulation tissue containing numerous neutrophils. There was no evidence of specific granuloma. Portions of the lung tissue adjoining the scar tissue showed a heavy infiltration of neutrophils. There were also a number of heavily pigmented macrophages. Further out, the inflammatory process was less severe.

Diagnosis.—Acute and chronic, nonspecific granulomatous pneumonitis with sinus formation was the diagnosis.

SUMMARY

Bronchial fistula is a serious complication following subphrenic abscess. It is usually due to delayed diagnosis and treatment.

The primary method of treating broncho-subdiaphragmatic fistula is to perform adequate drainage promptly and through a route that will not contaminate a serous cavity.

We have presented two cases. The first was a report of a subphrenic abscess of approximately two and one-half months' duration. The bronchial fistula was only of several hours' duration and the patient responded quite well to drainage alone. The second was a report of a subphrenic abscess of approximately twelve months' duration and a bronchial fistula of five months' duration. This was treated by drainage through the walled-off pleural cavity and a right lower lobectomy. One month later he began once more to expectorate large amounts of foul smelling purulent sputum. Adequate incision and drainage from the abdominal approach has so far produced a cure. The removal of the right lower lobe in the second case reported was probably not entirely justified and did not add to the patient's final recovery.

ADDENDUM

Mr. R. L. (Case 2) in February, 1953, had another episode of expectorating a large amount of purulent sputum. This responded to oral Aureomycin. Now the patient coughs up from 0 to 0.5 ounce of sputum a day but feels well and is doing light work and gaining weight. He refuses any further investigation at this time.

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TRAUMATIC CARDIAC SEPTAL DEFECT

Report of a Case in Which the Diagnosis Is Established by Cardiac Catheterization

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TO OUR knowledge, this is the first case in which the diagnosis of a traumatic rupture of the cardiac septum has been sustained by cardiac catheterization. Despite what appeared initially to be a gloomy prognosis, the victim suffers only moderate physical disability one year following the injury.

In recent years, nonpenetrating chest trauma has been well established as a cause of heart disease. Hemopericardium; fibrinous pericarditis; myocardial contusion and laceration; and rupture of valves, papillary muscles, and chordae tendineae have all been reported as a cause of heart disease. It is often difficult to make a precise anatomic diagnosis in the individual who survives major cardiac trauma, particularly where a septal rupture has occurred.

Bright and Beck, in 1935, reviewed the literature on nonpenetrating injuries of the heart.[1] Among 168 cases, there were 11 instances of tears in the interventricular septum and 1 instance of a tear in the interauricular septum; these were all demonstrated at autopsy. Warburg, in 1938, published a monograph on nonpenetrating cardiac trauma. He found, in 51 autopsied cases 1 instance of a rupture of the interventricular septum.[2] Anderson reported, in 1940, a nonpenetrating cardiac injury in a 30-year-old man. It was impossible to distinguish clinically between a rupture of the mitral valve and a rupture of the interventricular septum, although we believe the benign course favored the latter.[5] Bayrd and Gibson, in 1944, reported a case with clinical evidence of an interventricular septal defect in an 11-year-old child following an automobile accident.[3] In 1945 East published a report of a similarly clinically diagnosed condition in a 19-year-old boy.[4] In all of these reported cases a definitive diagnosis could be established only by autopsy.

CASE REPORT

C. H. T., a 21-year-old white soldier, fell asleep while driving an automobile on July 9, 1951. After the ensuing crash he did not regain consciousness for about one hour. At a local hospital he was treated for shock; a fracture of the medial condyle of the left humerus was splinted; and a superficial laceration below the left nipple was sutured. He was then removed to the Fort McPherson Army Hospital. He was dyspneic and he exhibited a persistent tachycardia upon arrival there. A chest x-ray picture showed

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The statements and conclusions published by the authors are the result of their own study and do not necessarily reflect the opinion or policy of the Veterans Administration.

Received for publication Nov. 20, 1952.

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cardiomegaly, and an electrocardiogram was interpreted as consistent with pericarditis. On July 11, 1951, he was transferred for further treatment to Lawson Veterans Administration Hospital, Chamblee, Ga.

On admission he was tachypneic, perspiring, and apprehensive. The pulse rate was 128 per minute. The blood pressure was 110/65 mm. Hg. Multiple abrasions were noted over the left forehead. A posterior splint was on the left upper arm and motion of the extremity was very painful at the shoulder. A clean, sutured, transverse laceration about 3 cm. long was present below the left nipple. The skin surrounding the nipple was contused. The respirations were rapid and shallow. There was an inspiratory lag over the left lower chest. The breath sounds were diminished over the left lower lung field anteriorly and laterally. The heart was not enlarged by percussion. A thrill could be felt in the left third intercostal space just lateral to the sternum. A loud, blowing systolic murmur was heard over the entire precordium. A slightly tender liver edge was felt 3 cm. below the costal margin. No ankle edema was present.

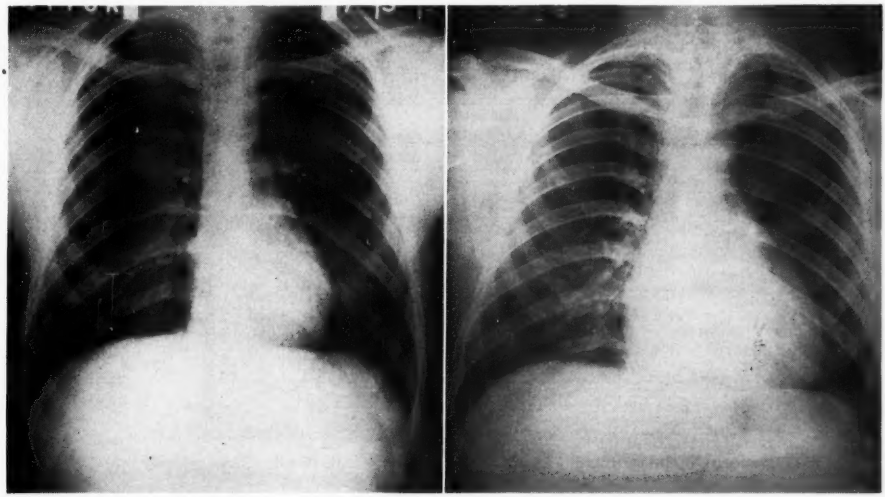

Fig. 1. Fig. 2.

Fig. 1.—Roentgenogram taken July 3, 1950, at pre-employment examination.
Fig. 2.—Roentgenogram taken Aug. 27, 1951, at Lawson Veterans Administration Hospital.

Examination of the blood revealed the hemoglobin to be 10.1 Gm. per 100 ml. and the hematocrit reading to be 30; these levels persisted throughout the hospital stay. The urinalysis was negative. Fluoroscopy of the chest on admission showed no evidence of a cardiac tamponade. A roentgenogram of the chest on admission revealed an enlarged heart, clear lung fields, and a moderate left pleural effusion. There were no rib fractures. A roentgenogram of the left shoulder showed a fracture of the head of the humerus in addition to the fracture of the medial condyle. An electrocardiogram on admission was interpreted as compatible with a cardiac contusion.

Careful and repeated questioning of the patient yielded no evidence of previous heart disease. Over a considerable period of time the following information was assembled: A pre-employment physical examination, performed on July 3, 1950, had revealed no evidence of heart disease. A roentgenogram of the chest taken on that occasion revealed an entirely normal heart (Fig. 1). In this film the transverse diameter of the heart is 11.4 cm.,

while in the roentgenogram taken at Lawson Veterans Administration Hospital on Sept. 27, 1951 (Fig. 2), the transverse cardiac diameter is 15.7 cm. In addition, the preinduction physical examination, on Oct. 17, 1950, showed no evidence of heart disease.

While at Lawson Veterans Administration Hospital, the patient was at first kept at strict bed rest and on a low salt diet. Oral procaine amide was given as a prophylactic measure. A bloody left pleural effusion was evacuated by repeated thoracenteses. Toward the end of the second hospital week, when he had been allowed a regular diet for several days, it was felt that he was lapsing into congestive heart failure; this was indicated by distention of the neck veins and jugular pulsations suggestive of tricuspid insufficiency. At that time the venous pressure was 144 mm. water, and the arm-to-tongue circulation time was twenty-two seconds. No specific treatment, other than salt restriction, was instituted. By the fourth hospital week the patient's condition appeared stable and he was allowed ward privileges. On limited activity he was not short of breath, had no orthopnea nor ankle edema, and maintained a constant weight. In an effort to clarify the diagnosis a cardiac catheterization was done on Aug. 29, 1951.* The findings of this study are shown in Table I. The discrepancy between the oxygen content of the blood in the right atrium

TABLE I. RESULTS OF CATHETERIZATION STUDIES

SITE	PRESSURE MM. HG		OXYGEN CONTENT VOL. %	OXYGEN SATURATION %
	INSTANTANEOUS	MEAN		
Superior vena cava	–	7	11.2	66
Right atrium	–	6.5	12.5	74
Right ventricle	27/6	15		
Mid			14.3	84
Outflow tract			14.9	88
Pulmonary artery	27/15	21		
Main			14.3	84
Left			14.2	83
Pulmonary capillary	–	11	–	–
Brachial artery	140/82	100	16.1	94
Basilic vein	–	15	–	–

Body surface area	1.88 m^2
Hemoglobin	12.5 Gm. per 100 ml.
Hematocrit reading	38.4
General blood volume	6910 ml. (3680 ml. per m^2)
Minute oxygen consumption	293 ml.
Blood flow L. per minute (1)	
Left ventricle	6.0
Right ventricle	16.3

and oxygen content of the blood in the right ventricle is characteristic of an interventricular septal defect. The discrepancy in the oxygen content of the superior vena caval and of the right atrial blood samples is not sufficiently large to indicate conclusively an atrial septal defect. An oxygen difference of 1.3 volumes per cent is equivocal and may well be due to a streaming effect.[6] The right atrial pulse contours show that no right ventricular blood was being regurgitated through an incompetent tricuspid valve at the time of the observation (Fig. 3). Unfortunately no more right atrial and vena caval blood samples were taken. The central pressures were somewhat elevated, but only to a degree consistent with the expanded general blood volume.[7] The great discrepancy between the outputs of the right and of the left ventricles suggests the large size of the septal defect.

In early September, 1951, the patient was transferred for disposition to Walter Reed Army Hospital. His course at that institution was entirely uneventful. Another cardiac catheterization was done on Nov. 1, 1951. The findings at that time suggested a large

*Performed at the Cardiovascular Laboratory of the Emory University School of Medicine.

atrial septal defect, but it is, unfortunately, not clear whether a tricuspid insufficiency existed at that time. The patient was retired from military service on Jan. 31, 1952, with the diagnoses of: (1) rupture of the cardiac septum due to trauma, (2) malunion of a simple fracture of the medial epicondyle of the left humerus, and (3) traumatic neuropathy of the left radial nerve.

The patient returned to sedentary clerical work in March, 1952. On a free diet his weight soon stabilized at its preaccident level. He experienced no untoward respiratory symptoms on mild physical activity although he became uncomfortably shortwinded on stairs, on upgrades, or on any effort beyond the ordinary. He had no orthopnea. He experienced occasional palpitations but otherwise no awareness of heart action nor chest discomfort. There was no swelling of the ankles. He took no medication.

When re-examined on July 21, 1952, he appeared in robust health. He briskly climbed a flight of stairs without obvious dyspnea. The blood pressure in both arms was 120/75 mm. Hg. The heart rate was about 100 per minute. The jugular veins filled only in recumbency and showed no pulsations characteristic of tricuspid insufficiency. The lungs were clear on auscultation. The liver was not palpable. There was no peripheral edema. The left elbow was limited by 10 degrees in extension, and the signs of the left radial neuropathy persisted. Inspection of the chest showed a diffuse apical impulse and a corresponding left border of percussion dullness, 2.5 cm. outside the midclavicular line in the fifth left interspace. The cardiac dullness was not increased elsewhere. Most intensely,

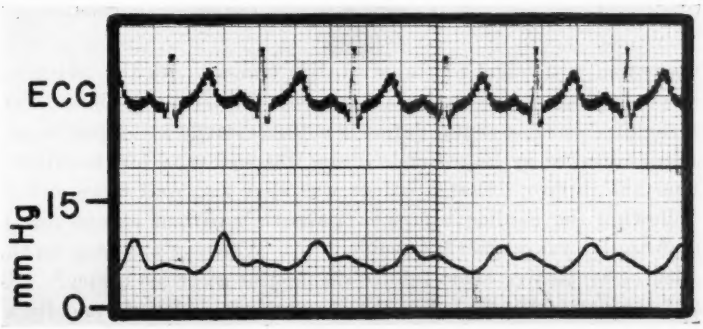

Fig. 3.—Right atrial pressure tracing obtained Aug. 29, 1951, during cardiac catheterization.

in the third interspace, just to the left of the sternum, could be felt a purring systolic thrill which was transmitted downward to the left costal margin. Similarly, in the same parasternal area could be heard, most intensely, an extremely loud, prolonged systolic murmur, widely transmitted toward the apex and the back. A rapid filling sound was audible at the apex. The pulmonic second sound was not accentuated. There were no other auscultatory abnormalities.

The hemogram was normal. The venous pressure in the cephalic vein at the junction of the mid and distal thirds was equivalent to 250 mm. water and did not rise significantly after a bicycle exercise for two minutes. The circulation time from the forearm to the tongue (Decholin) was twenty-seven seconds. Posteroanterior and oblique roentgenograms of the chest showed a generalized volumetric enlargement of the heart and normal lung shadows. Cardiac mensuration yielded values identical with those obtained from the film of Sept. 27, 1951 (Fig. 2).

COMMENT

While under observation at Lawson Veterans Administration Hospital there was much debate as to whether or not this man had congenital or acquired heart disease. It seems unlikely that so loud a murmur would have

escaped notice in the industrial and induction physical examinations. The classic history of a steering wheel injury to the chest, the striking differences in the cardiac silhouette by x-ray examination, and the findings at cardiac catheterization are convincing evidence that the septal defect was caused by the cardiac trauma. It is interesting that all who originally saw him gave a gloomy prognosis. It was supposed that he would soon succumb to rapidly progressive congestive heart failure. From a year's retrospect it is now apparent that hemodynamic equilibrium was achieved very shortly after the cardiac injury. Within a few weeks a hypervolemia developed, presumably as a compensatory response to the large intracardiac fistula.[8] It is now impossible to say whether or not at that time he had congestive heart failure, since the central pressures and the cardiac output were not measured under conditions of stress. Neither was the, perhaps crucial, measurement of glomerular filtration rate made. Although the problem was much debated, the patient was never given digitalis. One year after the accident the cardiac findings are unchanged and the functional status is only moderately impaired. The generalized cardiac enlargement of about 25 per cent strongly suggests a continued hypervolemia.[9]

This patient's survival of major cardiac trauma with the maintenance of fairly good cardiac compensation tallies with the meager published evidence that an acquired cardiac septal defect is not necessarily incompatible with life. The patient reported by Bayrd and Gibson was well until lost to follow-up 129 days after the injury.[3] East's patient was alive and well three and one-half years following the cardiac injury.[4] Anderson's patient enjoys full activity more than twelve years after his accident.[5, 10] Warburg's patient, on the other hand, died of congestive heart failure six months after his injury.[2] The longevity of the patients included in the case reports of Bright and Beck is not recorded.[1]

Our patient has an excessive pulmonary blood flow. This fact plus the large heart suggests that his septal defect has hemodynamically the same significance as a congenital high ventricular septal defect. It therefore seems likely that over a period of time he is likely to develop pulmonary vascular disease and ultimately right ventricular decompensation. Fortunately it will be possible to keep him under the continued medical surveillance of the Veterans Administration, and it is hoped that another cardiac catheterization may be done in a few years.

SUMMARY

1. An instance is reported in which a traumatically acquired cardiac septal defect was demonstrated by cardiac catheterization.

2. One year following the injury the subject is in good general condition and experiences no significant limitation of ordinary physical activity.

3. The patient has a large pulmonary blood flow which it is felt may ultimately lead to disabling pulmonary vascular disease.

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THORACOPLASTY WITH TEMPORARY EXTRAPERIOSTEAL LUCITE BALL PLOMBAGE

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INTRODUCTION

Lucite, known chemically as methyl methacrylate has other trade names such as Plexiglass, Crystallite, and Vitarillic. It is an acrylic resin of very high tensile strength, is relatively inert chemically, and does not deteriorate when implanted in the human body. It was introduced in 1938.

In 1940, Kleinschmidt, using it experimentally in animals to repair cranial defects, found it produced remarkably little inflammatory reaction.

In addition to being nonirritating to the tissues, it possesses the advantage over other foreign materials, which have been advocated for plombage, of being very light in weight so a large quantity can be used without the danger of penetrating pleura or thin-walled cavities.

Lucite is nonantigenic and noncarcinogenic. It softens at 105° C. and can be molded into any shape.

The serum which accumulates around the balls in the extraperiosteal space becomes organized into hyaline connective tissue, important in helping maintain early collapse.

HISTORY

Tuffier introduced extrapleural pneumonolysis in 1891. Since then, numerous plombage materials have been used, chiefly as extrapleural packs but also extraperiosteally. These materials include gauze, fat, muscle, rubber sheeting, paraffin, and Lucite. Although many increased the collapse obtainable, they had certain disadvantages and complications, notably:

(1) Accidental rupture into a lung or a thin-walled cavity; (2) hemorrhage into extrapleural space; (3) bronchopleural fistula; (4) infection of extrapleural space; (5) severe foreign body reaction from gauze, rubber, and paraffin; (6) expectoration of wax; (7) muscle atrophies; (8) migration of Lucite spheres into neck, mediastinum, and subcutaneous tissues of the chest wall.

Wilson first used Lucite spheres as a method of plombage in the collapse treatment of pulmonary tuberculosis, but after Trent's evaluation of extrapleural pneumonolysis with Lucite plombage, the procedure was hardly impressive. Trent, reporting a series of fifty-one cases, had a high incidence of complications and a high mortality rate. In addition to the previously mentioned complications, other noteworthy ones were dyspnea, mediastinal shift, severe chest pain, and cardiac embarrassment. In his series, there were eighteen deaths as a result of operation.

From Brandon Sanatorium, operate y the Sanatorium Board of Manitoba for the Department of National Health and Welfar dian Health Services.

Read at the Fifty-second Annual Meeting of the Canadian Tuberculosis Association at Regina, Saskatchewan, June 17 to 21, 1952.

Received for publication, Nov. 24, 1952.

Following a period of observation in June, 1950, at the Overholt Thoracic Clinic in Boston, we were strongly impressed by the procedure of temporary extraperiosteal Lucite plombage in thoracoplasty performed by this clinic and reported by Woods.[10]

ADVANTAGES OF THIS METHOD OVER CONVENTIONAL MODERN TYPE OF THORACOPLASTY

1. It is possible to have better and more selective collapse with the resection of fewer ribs and, therefore, conservation of more functional lung tissue. This is especially applicable to the limited apical five-rib thoracoplasty in which the scapula does not sink in.
2. There is no mediastinal shift or paradoxical movement which results in less postoperative shock, less difficulty in raising sputum, and less nursing care.
3. Improved collapse along the spine and paraspinal gutter, where tuberculous cavities are usually located, can be achieved.
4. The second stage, comprising removal of the balls and the ribs that were stripped of periosteum at the first stage, is performed three months after the first stage, so that there is ample time for recuperation between operations.
5. Complete collapse is obtained during first stage so there is no need to worry about rapid regeneration of new ribs, spoiling the result. As many as eight ribs have been stripped at the first stage.
6. Better results can be expected, as judged by conversion of sputum.
7. Complications are negligible.
8. There is less postoperative deformity.
9. Last, but not least, Lucite is easier to prepare and handle than wax, a common plombage material.

INDICATIONS AND CONTRAINDICATIONS

These are the same as for conventional thoracoplasty. A completely destroyed lung is not amenable to this method and should be treated by a conventional multi-stage thoracoplasty or resection. We have not used the procedure for more than an eight-rib thoracoplasty. In one case, it was impossible to insert the spheres due to retraction and overlapping of the ribs caused by fibrosis. This patient had had long-standing pneumothorax previously. She was treated by conventional thoracoplasty.

OPERATIVE PROCEDURE

Local anesthesia has been used in all cases, in conjunction with mild basal narcosis. The patient is placed in the same lateral position as for conventional thoracoplasty, and the usual curved parascapular incision is made.

After deciding from preoperative x-ray photographs the lower level of collapse to be attained, the ribs are stripped of their periosteum to this level posteriorly. The first and second ribs are stripped as far past the costochondral junction as possible and the others progressively less far anteriorly, so that the resulting collapse is horizontal at its base. One does not have to strip the lower ribs as far anteriorly as in the conventional thoracoplasty. In fact, this must be borne in mind; otherwise, more collapse will be obtained than is desired.

The first rib is stripped only on its outer edge and under surface, so that the muscle attachments to the upper surface will prevent the spheres from escaping into the neck.

The lung is further relaxed along the spine by severing the intercostal muscles posteriorly at a point just under the transverse processes, where a curved forceps is easily passed between the muscles and the bundle of nerve, artery, and vein. The surgeon then cuts down on the forceps; thus the blood supply to the pack bed is preserved. The lung is further eased away from the neck of the ribs and spine by very gentle stripping with the index finger until resistance is met. In this manner excellent collapse is obtained posteriorly. Bleeding is carefully controlled throughout.

After irrigating the wound with normal saline solution, the Lucite balls are inserted between the ribs on the outside and the underlying intercostal muscles and periosteal rib beds. Enough balls are used to make a snug pack without producing too much pressure on the underlying lung. A record is made of the number of balls used so that, at removal, every sphere can be accounted for. As many as thirty balls have been used at one time.*†

Next, using continuous No. 2 chromic catgut on a large curved needle, the periosteum and the attachment of the serratus magnus, that has been stripped from the second rib and has come to lie above the first rib, are sutured back down to the second rib; then the same catgut is woven around other stripped ribs, passing over any balls that tend to pop out and pulling the ribs closer together where necessary to prevent the balls from escaping between the ribs. Thus the balls are enclosed behind a meshwork of ribs and catgut. To date, we have had no balls escape or migrate. At this point, 10 c.c. of sterile distilled water containing 200,000 units of crystalline penicillin and 1 Gm. of streptomycin calcium chloride complex are instilled around the balls. Thereafter, the chest wall is closed. One thousand cubic centimeters of 5 per cent glucose and saline are administered intravenously when the patient returns from the operating room. Blood transfusion has not been required.

POSTOPERATIVE COURSE

On the third postoperative day, aspiration of the space is attempted, and generally 50 to 150 c.c. of serosanguineous fluid are obtained. This fluid is replaced by penicillin and streptomycin, instilled in the same dosage as previously mentioned. Usually, these patients run a low-grade fever for three to four days after operation. It is our practice to give streptomycin and PAS pre- and postoperatively for a period ranging from three to sixteen weeks, depending on the severity of the disease before operation.

New ribs are produced from the periosteum beneath the balls. Regeneration in the collapsed position is much slower than with the conventional thoracoplasty, so that the new ribs are sometimes not visible radiologically for two to three months after the second stage, but the formation of connective tissue main-

*Lucite balls are manufactured by Codman & Shurtleff, Inc., 104 Brookline Avenue, Boston, Mass. They are available in sizes 1, 1¼ and 1½ inches in diameter.

†Sterilization procedure followed: Scrub Lucite balls with green soap and water; wash off with alcohol; soak in Zephiran Chloride solution, 1:1,000, at least forty-eight hours.

Fig. 1.

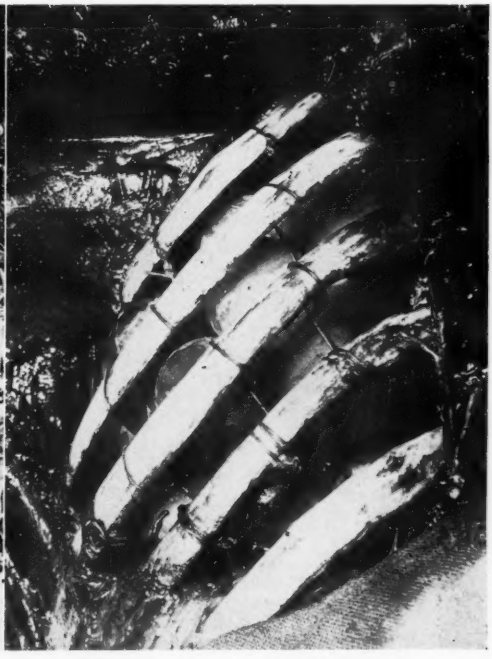

Fig. 2.

Fig. 1.—Ribs stripped of periosteum, ready for insertion of Lucite balls.
Fig. 2.—Lucite balls fixed in place with catgut, ready for closure of chest wall.

Fig. 3.—At the second stage the ribs previously stripped of periosteum and balls are removed, leaving excellent collapse, especially along the spine at the bottom of the picture. The first rib is left, since its removal does not increase the collapse. It is prominent at the right.

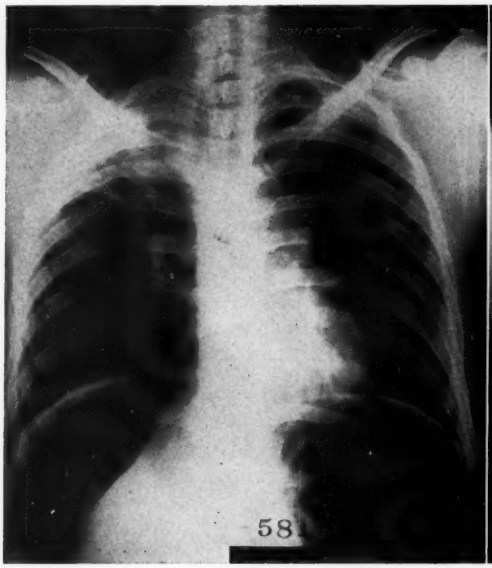

Fig. 4.

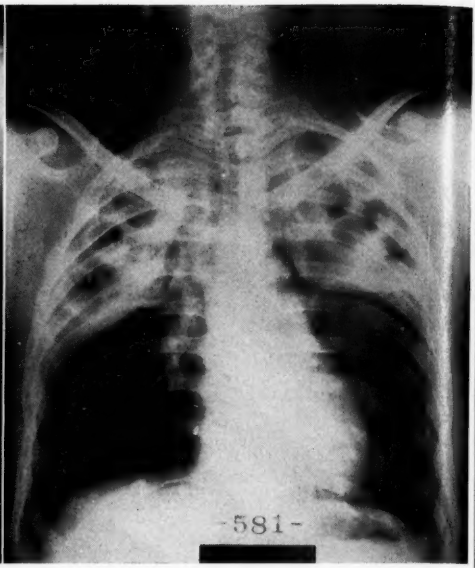

Fig. 5.

Fig. 4.—Preoperative x-ray film of a patient with bilateral apical cavitary disease. Sputum positive.

Fig. 5.—Same patient. Lucite balls in place.

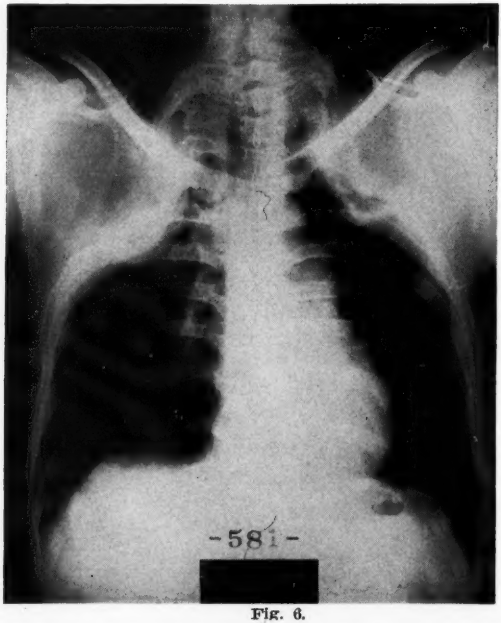

Fig. 6.

Fig. 6.—Same patient. Final result. Gastric culture negative for tubercle bacilli. Note first rib was removed on left side but left intact on right. Scapula did not fall, so there was no postoperative deformity.

tains the desired collapse until the new ribs appear. After three to five months, the original ribs are resected and the balls removed. It has been our practice not to resect the first rib, since its removal does not increase the collapse. The new ribs are found firmly joined to it and, by leaving it with its muscle attachments, it is felt that less postoperative deformity results. If the sixth and seventh ribs are stripped at the first operation, it is our practice not to resect them, so that the scapula will not fall in, again minimizing deformity. With larger thoracoplasties, of course, it is advisable to let the scapula fall in order to obliterate the large subscapular space created. Ribs are resected up to the transverse processes, but the transverse process itself is left intact.

PRESENT SERIES

All the patients included in this series of operations were treaty Indians. Of the forty-three patients, four had bilateral operations. Twenty-six patients (60 per cent) were between the ages of 16 and 30, eight were 15 years or less, and the eldest patient was 51 years old.

Extent of Disease Preoperatively.—Thirty-eight patients (88 per cent) had moderately or far-advanced disease, with cavitation.

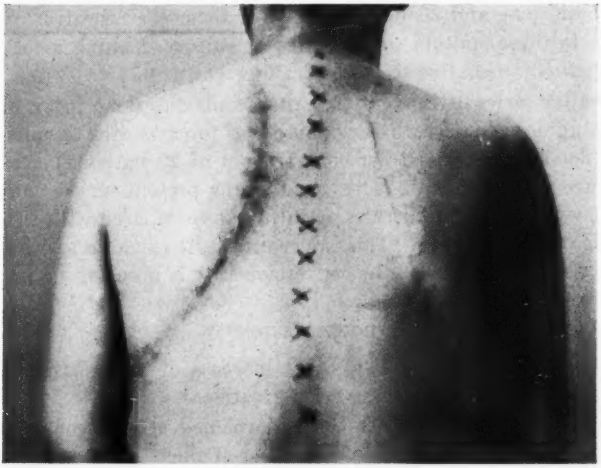

Fig. 7.—Same patient. Note lack of deformity.

Bacilli.—Immediately before the operation, thirty-two patients (74 per cent) were positive to smear or concentrate and another nine had positive cultures, bringing the percentage of those positive up to 95 per cent. All but one case had been positive at some time before operation.

Contralateral Disease.—Twenty-six patients (60 per cent) had established disease of varying extent in the other lung. In 5 cases, thoracoplasty had already been performed.

Previous Treatment.—The majority had had pneumoperitoneum, and practically all had had streptomycin alone or combined with PAS prior to the opera-

tion. All but one patient had these drugs covering the period of surgery, and twenty-five patients (58 per cent) continued to receive them for a period of sixteen weeks.

Extent of Thoracoplasty.—The summarized data of the extent of thoracoplasty in the forty-three patients follow: five ribs were stripped in seventeen cases or 40 per cent; six ribs were stripped in 14 cases or 33 per cent; seven ribs were stripped in 9 cases or 20 per cent; eight ribs were stripped in 3 cases or 7 per cent.

In other words, 73 per cent had six ribs or less stripped of periosteum at the first stage and had only five ribs resected three months later, so that in this proportion there was no falling in of the scapula and, consequently, a minimum of deformity.

RESULTS

Gastric cultures are not done in our institution until six months after the first stage lest the effect of the streptomycin, usually given during surgery, yield some falsely negative results. With this proviso in mind, we are able to report that, since this procedure was first employed in November, 1950, nineteen months ago, of 27 patients operated on prior to six months ago, 27 gastric cultures have been done and 20 (74 per cent) of them are negative. Twenty-four are negative to three sputum concentrates or culture, making a total of 89 per cent of the patients negative to concentrate or culture.

Of a similar series of conventional thoracoplasties done prior to November, 1950, including only those with resection of up to eight ribs to correspond with the Lucite plombage series, 62 per cent (18 out of 29 patients) are negative to gastric culture compared with 74 per cent in the present series, and only 19, or 66 per cent, negative to concentrates or culture, as compared with the 89 per cent in the Lucite plombage series. This, we realize, is too small a series to be significant, but it would appear that the conversion rate is going to be increased with this procedure.

COMPLICATIONS

Two cases (4 per cent) had a slight increase of pre-existing contralateral disease, but both are now clearing with treatment.

Three of the 43 cases (7 per cent) developed spontaneous pneumothorax after the first stage, due to accidental tearing of pleura. This, however, turned out to be of no consequence; the lung in each case re-expanded normally, and good collapse was obtained. There have been no cases of blocked sputum, no wound infections, and no other complications. There have been no deaths.

A personal communication from Dr. F. M. Woods states that the Overholt Clinic has now used this procedure in 300 to 400 cases and it has continued to give excellent results. A slight modification has been made insofar as they now place a polyethylene sheet around the Lucite spheres in order to distribute the pressure of the balls a little more evenly and to prevent the rare possibility of a ball slipping out between the ribs. Also, in nearly all cases, the pack is being left in permanently. Up to the present time, they have had only two cases of infection.

CONCLUSION

Temporary Lucite plombage is presented as a possible improvement over the conventional modern type of thoracoplasty in that it gives a more selective collapse, a higher incidence of sputum conversion, less skeletal deformity, less postoperative complications, and requires fewer stages of operation.

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UNUSUAL ANEURYSM OF A PULMONARY ARTERY

Report of Case in Which Treatment Was Surgical*

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WE CONSIDER a case, involving an aneurysm of a pulmonary artery recently encountered at the Mayo Clinic, sufficiently unusual in its characteristics to merit publication. This general subject was thoroughly reviewed by Boyd and McGavack[1] in 1939 and by Deterling and Clagett[2] in 1947. One hundred and forty-seven cases were reported and confirmed by necropsy up to September, 1946. No cases, however, were reported in which the aneurysm had been surgically removed. Since that time we have found reports of two cases of aneurysm of the pulmonary artery in which an attempt at surgical treatment was carried out. Blades, Ford, and Clark,[3] in 1950, described an aneurysm of the left pulmonary artery and artery to the lower lobe of the left lung which was causing symptoms. On exploration it was found impossible to treat the aneurysm, without sacrificing the artery to the left upper lobe, because of the position of the aneurysm in relation to the origin of the artery to the upper lobe. The left pulmonary artery was ligated near its origin and the vessels continuing from the aneurysm in the lung were ligated.

Hohlweg[4] in 1948 presented a case in which lobectomy was done for a traumatic aneurysm of the pulmonary artery. Since the review of Deterling and one of us (Clagett)[2] in 1947, three cases have been reported in which the condition was proved by necropsy, one each by Clifford, MacGillivray, and Goodale,[5] Lindert and Correll,[6] and Crumpton.[7] Grelland[8] reported a case in which diagnosis was established by angiocardiography. The patient apparently was not treated surgically and was alive at the time of reporting. Dotter and Steinberg[9] reported two cases in which congenital aneurysm of the left pulmonary artery had been diagnosed by angiocardiography and had not been treated. They wrote that surgery in this condition is contraindicated. The statistics of Detterling and one of us (Clagett) and of Boyd and McGavack[1] do not bear this out.

CASE REPORT

Clinical Data.—The patient was an asymptomatic dentist, 28 years old, who was first seen on March 27, 1951. He registered with the diagnosis of arteriovenous fistula in the left lung.

At the age of 5 years he was found to have a systolic murmur in the left side of the thorax, and throughout his life he had been suspected of having a defective mitral valve,

Received for publication Dec. 11, 1952.

*The data on cardiac catheterization were made available through the courtesy of Dr. Earl H. Wood. Appreciation is extended to Dr. Howard B. Burchell for help in preparation of this paper.

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"probably due to old rheumatic fever." He had been advised to restrict his activities; nonetheless, he had been active in sports at school and was able to hunt and hike without difficulty. There was no history of cyanosis.

The patient said that he had chronic postnasal drip and that he had a very slight cough which occasionally was productive of a small amount of sputum. In October, 1950, he had been deferred for military service because of the loud systolic murmur in the left side of the thorax.

At another hospital, investigation recently had been carried out and had included angiocardiograms. Results of this investigation were said to be consistent with a diagnosis of arteriovenous fistula in the upper lobe of the left lung. In the past history the only significant feature was a history of very severe pneumonia in the patient's mother when the patient was three months in utero.

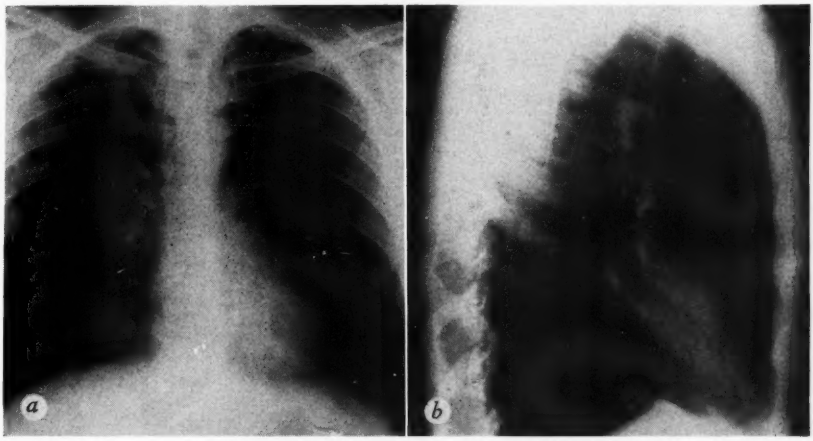

Fig. 1.—*a*, Posteroanterior roentgenogram and *b*, lateral roentgenogram of the thorax, showing shadow in upper lobe of the left lung. This mass pulsated when observed roentgenoscopically.

The patient was a well-developed, healthy-looking white man. The only positive finding was the systolic murmur. This was described as being moderately loud, well heard over both sides of the upper and anterior part of the thorax and slightly louder to the left of the sternum. Posteriorly the murmur was heard with the same intensity in the left interscapular area. At times the murmur was continuous, particularly just at the end of deep inspiration. Exercise had no effect on the murmur. No thrill could be felt. Blood pressure in the arm, in millimeters of mercury, was 110 systolic and 55 diastolic. The pulse rate was 60 beats per minute. Blood pressure in the legs was 140 systolic and 74 diastolic, equal on each side.

Results of urinalysis were normal; the value for hemoglobin was 15 Gm. per 100 c.c. of blood, erythrocytes numbered 4,950,000 and leukocytes, 9,800, per cubic millimeter of blood. The sedimentation rate was 9 mm. in one hour (Westergren); reaction of the serum flocculation test was negative; the blood group was 0, Rh positive.

The electrocardiogram showed a rate of 56, sinus arrhythmia; right axis deviation in the standard, and normal precordial leads.

Roentgenograms of the thorax (Fig. 1) including posteroanterior and left lateral views were interpreted as showing a vascular anomaly in the upper lobe of the left lung. This appeared as a large vessel 1.5 cm. in width and 6 cm. in length.

Fluoroscopy showed the vascular anomaly, above the left hilus, to be pulsating rather vigorously as compared to the remainder of the pulmonary arteries at the hila.

Studies of arterial oxygen saturation carried out by the ear oximeter method of Wood, and the percentages for saturation were: at rest, 98.2; standing, 98.5; after five minutes' exercise at 2 miles per hour, 98.4; after breathing 100 per cent oxygen for seven minutes, 100. The circulation time from lung to ear was 2.3 seconds.

Fig. 2.—Positive roentgenogram of injected specimen, showing the aneurysmal dilatation of the pulmonary artery in the upper lobe of the left lung and the proximal part of its branches.

It was believed that results of these oximetric studies excluded a pulmonary arteriovenous fistula, unless the shunt was very minimal or there was anomalous venous drainage of the upper lobe of the left lung.

Cardiac catheterization was recommended for determination of the pressure in the pulmonary artery and to exclude the possibility of anomalous pulmonary drainage or a patent ductus arteriosus. The results are synopsized as follows:

In the right atrium the systolic pressure was 8; diastolic, 0; oxygen saturation, 82 per cent.

In the superior vena cava the systolic pressure was 8; diastolic, 0; oxygen saturation, 83 per cent.

In the inferior vena cava the systolic pressure was 6; diastolic, 0; oxygen saturation, 80 per cent.

In the left subclavian vein the systolic pressure was 5; diastolic, 0; oxygen saturation, 83 per cent.

In the right ventricle the systolic pressure was 73; diastolic, 8; oxygen saturation, 82 per cent.

In the pulmonary artery the systolic pressure was 60; diastolic, 10; mean, 18; oxygen saturation, 81 per cent.

The cardiac index was 2.94 liters per minute.

Surgical Data.—Surgical exploration was carried out on Nov. 17, 1951, by one of us (Clagett) through a left posterolateral incision. A free pleural space was encountered. The fissures between the lobes were well demarcated. The pulmonary artery as it left the heart did not appear to be particularly enlarged; the pulmonary veins were essentially normal.

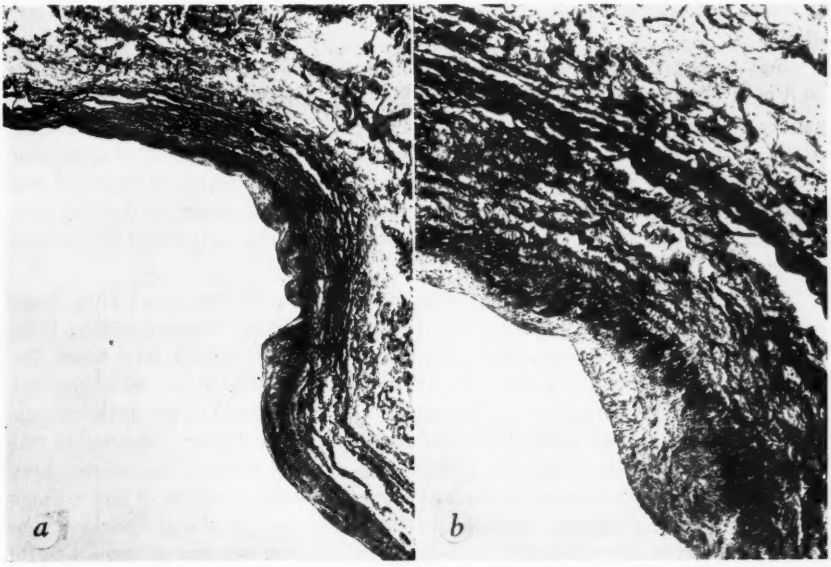

Fig. 3.—Photomicrographs of the wall of the dilated pulmonary artery; *a*, ×30; *b*, ×100. In *a* there are shown the variation in the thickness of the wall and an area of slight internal proliferation. In *b* the area of internal thickening and the irregular fragmentation of the elastic lamina may be seen.

In the upper lobe of the left lung a large pulsating mass could be felt. There was a palpable thrill over this area almost identical with that produced by a patent ductus arteriosus. In the lower lobe of this lung the same process was palpable to a much lesser degree; the vessels were slightly enlarged and there was a slightly palpable thrill. Lobectomy was decided upon.

The vessels to the upper lobe were individually ligated and the lobe was removed.

Pathologic Data.—There was moderate fusiform dilatation of the pulmonary artery to the upper lobe of the left lung. The lesion in the collapsed artery and lung appeared to be smaller than when felt in vivo.

The pulmonary artery in the upper lobe was injected with radiopaque gelatin substance. Roentgenograms were then made of the specimen. In Fig. 2 a positive version of the roentgenogram is seen. The marked enlargement of the left pulmonary artery is evident. It is also apparent that there is no evidence of arteriovenous fistula.

Sections of the wall of the aneurysm are seen in Fig. 3. The walls varied in thickness, showing areas of fragmentation of the elastic lamina and other areas of mild internal proliferation (Fig. 3, *a* and *b*).

Postoperative Data.—The patient made an uneventful recovery, but postoperatively he still had a systolic murmur in the left side of the thorax only slightly less intense than the original murmur. He was discharged on Nov. 28, 1951.

COMMENT

The lesion in the left side of the thorax producing the opacity on the roentgenogram (Fig. 1) was fairly definitely established to be related to the vascular system by fluoroscopy and by review of the angiocardiograms made elsewhere. Cavernous hemangioma of the lung and patent ductus arteriosus with an associated pulmonary aneurysm each was considered in the differential diagnosis.

The normal oxygen saturation of the blood within the right side of the heart and pulmonary vessels combined with the radiologic findings on straight posteroanterior and lateral roentgenograms, and fluoroscopy and angiography of the thorax all were strong evidence in favor of the diagnosis of aneurysm of the pulmonary artery. Considering the early age at which the patient was known to have the previously noted murmur and in the absence of other etiologic factors, the lesion might be suspected of being a congenital pulmonary aneurysm.

Etiologically, the condition is obscure and must be set apart from those cases in which there are aneurysms (usually saccular) consequent to long-standing pulmonary hypertension or high pulmonary blood flow most frequently associated with a patent ductus arteriosus.[10] The presence of the pulmonary systolic hypertension in this case is a finding that has not been encountered previously in our laboratory, and would indicate either a decreased pulmonary arterial distensibility or a decreased systolic runoff. The mean pressure in the pulmonary artery was planimetrically determined as 18 mm. of mercury and was only slightly elevated. The persistence of the systolic murmur after operation is unexplained. It is, however, of some concern in respect to the possibility that other pulmonary arteries are similarly, although less, affected by a degenerative process.

The average age of the patient at death in the conglomerate group of aneurysms of the pulmonary artery reported by Deterling and one of us (Clagett) was 42.8 years in men and 39.3 years in women. In the entire series of 142 patients, among those whose age was known, 30 per cent died before the age of 30 years. This seems sufficient evidence to indicate the necessity for an attempt at surgical treatment for those people who have an isolated aneurysm of the pulmonary artery.

SUMMARY

A case of localized aneurysmal dilatation of a large branch of the pulmonary artery is presented. Physiologic studies ruled out an arteriovenous communication and established an unusual type of pulmonary systolic hypertension. Successful surgical treatment was carried out.

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THE REACTION OF PULMONARY TISSUE TO LIPIODOL

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SINCE the introduction of bronchography using iodized oil by Sicard and Forestier in 1922,[1] this diagnostic technique has received widespread use. They believed the material to be entirely harmless and introduced it into the caudal epidural space and spinal subarachnoid space of human beings before undertaking to inject it into the tracheobronchial tree. Bronchography is a procedure that is generally considered to entail little risk. The hazards that exist, aside from those associated with the topical anesthesia employed, are of two types. The first, an untoward reaction to iodine, although rare, is well recognized and may be serious. The second, which is the subject of this report, is the local tissue reaction to iodized oil. The terms "lipidol," "Lipiodol," "iodized oil," "Neohydriol," etc. used in this discussion when individual reports are cited are used in the same manner as they were found in the original article. When two or more reports are cited together, the term "iodized oil" may refer to any of several preparations of iodized oil used in contrast radiography, usually 40 per cent iodized poppy-seed oil.

Studies of the pulmonary reaction to iodized oil in experimental animals have shown in general that the oil is almost entirely eliminated by way of the tracheobronchial tree and at most calls forth only a phagocytic response confined to the lumens of the alveoli and bronchi.[2-10] If large amounts of iodized oil are instilled intrabronchially, atelectasis and nonspecific pneumonitis may result.[11] Gowar and Gilmour,[12] however, found many nodules of epithelioid cells, some with foreign body giant cells, surrounding oil droplets in the lungs of rabbits which had received intrabronchial injections of viscous Neohydriol, which is composed of the iodized glycerin esters of the fatty acids of poppy-seed oil. These changes were not seen in animals that had received nonviscous Neohydriol (iodized ethyl esters of the fatty acids of poppy-seed oil). Chesterman[10] also found what he described as a lipoid pneumonia in three cats that had been given intrabronchial injections of Neohydriol. He found no reaction in the lungs of cats that had received Lipiodol or Iodatol.

A number of cases of presumed reactions to retained iodized oil in the human lung have been reported. Brody[13] and Fortner and Miles[14] described granulomatous reactions to iodized oil retained in the lung for one month and one year, respectively. The first instance was in a region distal to a bronchus obstructed by carcinoma. In the second there was pulmonary tuberculosis and bronchiectasis. Histologically in both, oil droplets were found to be enclosed within a granulomatous foreign body reaction. In the case reported by Brody roentgenograms of slices of tissue from the region demonstrated radiopaque

From the Departments of Surgery and Pathology of the Yale University School of Medicine in contract with the Office of Naval Research, Project N6ori-44, Task Order XI.
Received for publication Dec. 19, 1952.

areas compatible in size and distribution with the oil droplets seen histologically. Storrs, McDonald, and Good[15] described a large granulomatous lesion enveloping oil droplets in the left lower lobe of a surgical specimen showing bronchiectasis. This was removed three weeks following bronchography with Iodochloral (iodized and chlorinated peanut oil). Chemical analysis of the tissue from the granuloma yielded 300 times the iodine content of adjacent normal lung tissue. All of the three cases just cited had the typical histologic form of a lipogranuloma. Wright[16] reported a case with a somewhat different histologic appearance where Lipiodol had been trapped behind an obstructed bronchus for one year. There was a dense reticulated mass formed by many phagocytic cells containing oil and a granulomatous reaction in the pleura with oil droplets in the tissues and in phagocytic cells. Rabinowitch and Lederer[17] related, without giving the details, the case of an elderly man who had a lipoid pneumonia at autopsy, having just previously received an intratracheal injection of iodized poppy-seed oil.

The effect of iodized oil in other tissues of the body has been investigated. Peiper and Klose[18] and Lindblom[19] found no granulomatous reaction to iodized oil injected into the dural space of rabbits. Brown and Carr[20] and Garland[21] reviewed the experimental, clinical, and pathologic evidence regarding the effect of iodized oil on the meninges and concluded that in the majority of cases the oil remains in lakes and is movable. Later there may be some fibroblastic proliferation about the oil, but the changes are confined to the meninges and do not affect the underlying neural tissues. However, Craig,[22] Boldrey and Aird,[23] and Davis, Haven, and Stone[24] found small granulomatous nodules about vacuoles in the meninges of dogs following the intrathecal injection of iodized oil. In the former two studies no fat stains were performed on the tissues and in the latter the experiment was complicated by the performance of a laminectomy with the introduction of a rubber tube into the spinal canal in order to produce a block.

Lash[25] reported the finding of three small pelvic cysts containing oil, which were found to liberate iodine on saponification, in a patient on whom uterosalpingography had been performed using Lipiodol. The cyst wall contained small vacuoles surrounded by giant cells and epithelioid cells, but no lipid stains were performed on the tissues. Reis[26] and Rubin[27, 28] described what they considered to be granulomatous lesions of the Fallopian tubes following uterosalpingography with Lipiodol. No mention was made of lipid stains of the tissues, and the histologic findings were not illustrated.

Crandall and Walsh[29] and Tabern and his co-workers[30] described the occurrence of a fibrinous pericarditis and pleurisy when Lipiodol or Lipoiodin was introduced into the pericardial and pleural cavities of experimental animals. Lindskog and Tennant,[31] however, found no reaction to small amounts of Lipiodol following injection of this material into the pericardial cavity of cats, the oil remaining apparent radiographically as long as one year.

The fate of iodized oil remaining in the lung is of considerable clinical as well as experimental interest. Most of the histologic observations made in this regard have been incidental to the investigation of the possible deleterious

effects of the oil. The length of time that iodized oil remains in the lung is variable. It may remain as long as seven months in normal experimental animals.[6, 8] In unusual circumstances iodized oil has been retained in human lungs for as long as one or two years.[14, 16, 32, 33] Ballon and Ballon[3] stated that Lipiodol is retained longer in the healthy lung than in the diseased lung unless it is trapped peripheral to an obstructed bronchus where it may persist. Fried and Whitaker[2] found that iodized oil disappeared more rapidly from the lungs of cats with upper respiratory infections than from the lungs of normal cats. Weinberg,[11] however, stated that iodized oil persisted longer in regions of pneumonitis artificially produced by previous ligation of a bronchus of a guinea pig than in the normal guinea pig lung.

Most writers in describing histologic material from experimental animals and specimens from human beings have stated that iodized oil may be phagocytized. Pinkerton[5] on the other hand stated that poppy-seed oil in the lungs of dogs and rabbits is not included in macrophages, and others consider phagocytosis of iodized oil to be minimal.[9, 12] Iodized oil has been described as being present in pulmonary lymphatic vessels,[4, 7] Bezançon, Delarue, and Valet-Bellot[34] stating that this material could be found in the interstitial spaces of the lung from a patient who had received Lipiodol seven years previously. Others believe that the oil is not eliminated by way of the lymphatics.[5, 12] Iodized oil has been described as being present in the bronchial wall and even in the cells of the bronchial cartilages,[3, 11] Sato[7] stating that it may be seen in the walls of the bronchi in lymphatic vessels within two hours after intratracheal administration and within the cells of the bronchial cartilage within two days. Histologic studies regarding the presence or localization of iodized oil are subject to considerable question. Examination of frozen sections of lung tissue is not completely satisfactory for the study of anatomic details. More important is the fact that in all of the investigations just mentioned only standard lipid stains were employed to identify the iodized oil. Graef[35] and Black[36] studied the staining reactions in lung tissue of various animal, mineral, and vegetable oils, including iodized poppy-seed oil, using various lipid stains. They found that while mineral oil and paraffin can be identified by a series of reactions, there is no specific shade or tint uniformly characteristic of a particular fat. There is normally a moderate amount of fat in the lung. Particularly it occurs as adipose tissue in the walls of the bronchi and as minute droplets in the cells of the bronchial cartilages.[37] Moreover, it is well known that infiltration with fat and fat-filled macrophages is a prominent feature of the organizing pneumonitis associated with many chronic pulmonary diseases, especially distal to obstructing lesions.

The present report deals with the results of a histologic study of a series of resected lung specimens from patients who had been previously subjected to bronchography with iodized oil. The purpose of the investigation was to determine the presence and location of residual iodized oil as well as to determine the presence of any histologic changes attributable to the contrast medium, utilizing a staining technique which differentiates iodized oil from other fat in the lung.[38]

MATERIAL

Thirty-seven lung specimens from thirty-four patients were selected at random for investigation from patients who had received intratracheal injections of iodized oil three weeks to forty-seven months prior to operation. The specimens varied from a single pulmonary segment to an entire lung. Bronchiectasis was present to some degree in all of the specimens, and all contained some areas of organizing pneumonitis. In three of the specimens there was a chronic lung abscess in addition to bronchiectasis. In three patients bronchography had been performed at an outside hospital, and the type and amount of contrast medium were not known. In the remainder bronchography was performed at the New Haven Hospital, and Lipiodol was used in each instance. The amount used was usually 20 c.c. and never exceeded 30 c.c. The lot number of the Lipiodol was available in many cases.

In thirty-three instances the opportunity was afforded to review roentgenograms of the chest taken within a few days (in the majority of cases, one day) prior to operation and to correlate the radiographic evidence of retained Lipiodol with the histologic findings.

From two to six blocks were taken from each specimen for microscopic study. The blocks were imbedded in 10 per cent gelatin and fixed in 10 per cent formalin prior to sectioning on the freezing microtome. The staining technique, which has been described elsewhere,[38] depends for its specificity for Lipiodol upon the precipitation of iodine as silver iodine utilizing silver nitrate. Preliminary staining with brilliant cresyl blue identifies lipid material in the section including Lipiodol. Lipiodol in sections stained in this manner assumes a characteristic dark brown appearance easily differentiated from other lipid material which appears pink. Paraffin-imbedded sections stained with hematoxylin and eosin from each specimen were also examined. In most cases blocks were taken adjacent to the blocks stained by the special technique. Sections of lymph nodes from twenty specimens stained by this method were also examined.

OBSERVATIONS

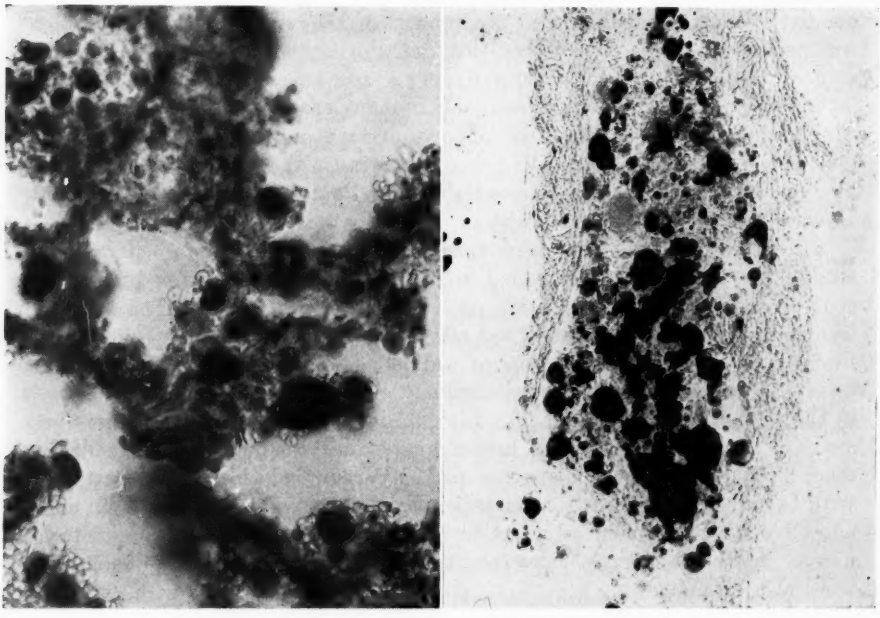
The histologic findings are summarized in Table I. In fourteen specimens no Lipiodol was apparent histologically. Preoperative roentgenograms were available in thirteen of these fourteen cases, and in none was Lipiodol demonstrable radiographically in the portions resected. In three patients,

TABLE I. SPECIFIC STAINS FOR LIPIODOL OF 37 LUNG SPECIMENS

PRESENCE AND SITE OF LIPIODOL	DAYS AFTER BRONCHOGRAPHY	NUMBER	PERCENTAGE
I. No Lipiodol demonstrable microscopically	1,404 to 46	14	38
II. Lipiodol present microscopically	295 to 23	23	62
A. Lipiodol granulomas present	109 to 29	6	16
B. Lipiodol concentrated in areas of organizing pneumonitis	295 to 42	7	19
C. Lipiodol free or phagocytized in alveolar and bronchial lumens	145 to 23	10	27

however, residual Lipiodol was visible by x-ray examination in other regions of the lung (46, 77, and 90 days after Lipiodol bronchography). The fourteen patients had received intratracheal Lipiodol 1,404 to 46 days prior to operation.

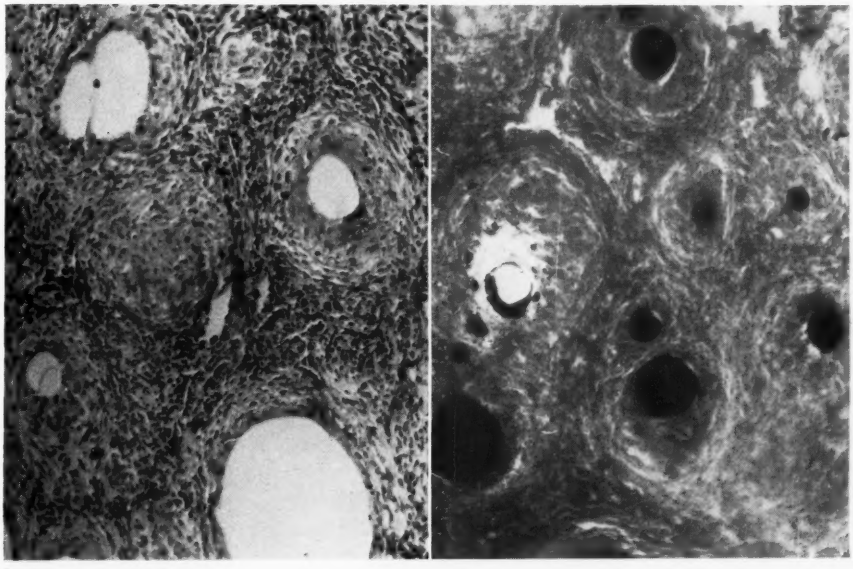
In twenty-three specimens residual Lipiodol was demonstrated histologically. Roentgenograms were available in twenty of these cases and residual Lipiodol was demonstrable in all except two (79 and 295 days after Lipiodol administration). In ten of these specimens the Lipiodol droplets



A. *B.*

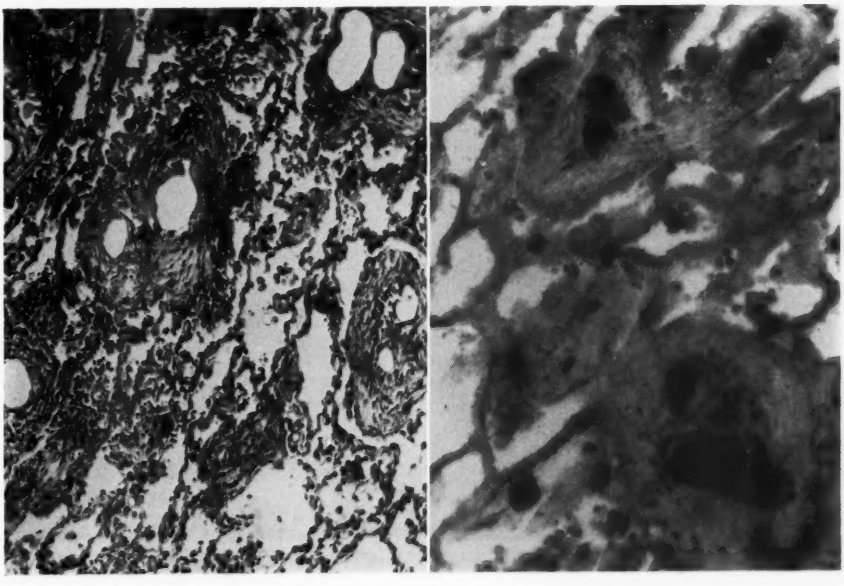
Fig. 1.—Free and phagocytized Lipiodol droplets in alveolar spaces, *A*, and in the lumen of a small bronchiole, *B*. The Lipiodol appears as black ameboid masses and can be easily differentiated from other lightly staining fatty material. Specimens taken from patients both of whom received intratracheal Lipiodol five weeks prior to surgery. Stained with brilliant cresyl blue and silver nitrate.

were found free or phagocytized in alveolar spaces or bronchial lumens without being involved in cellular reactions (Fig. 1). In six specimens, granulomas containing Lipiodol droplets were found. All had the form of a rather characteristic granuloma with fat droplets surrounded by epithelioid cells and foreign body giant cells encapsulated within fibrous connective tissue (Figs. 2 and 3). The fat in each case was demonstrated to be Lipiodol. The lesions varied from microscopic nodules within relatively normal lung tissue to dense granulomas visible grossly. The granulomas were focal, usually subpleural, and macroscopically they appeared as well-circumscribed, firm, yellow-white regions (Fig. 4). These six patients had received intratracheal



A. *B.*

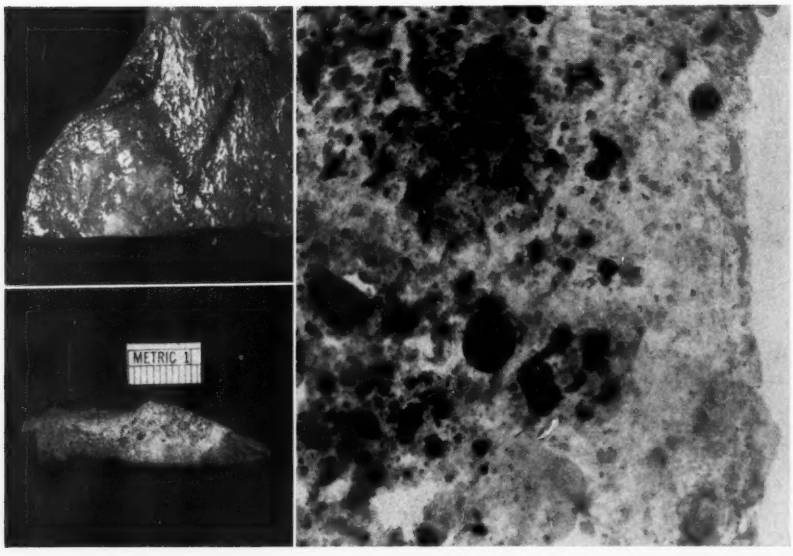
Fig. 2.—Foreign body granuloma surrounding Lipiodol droplets. Lipiodol administered fifty-seven days before resection. *A*, Hematoxylin and eosin. *B*, Brilliant cresyl blue and silver nitrate.



A. *B.*

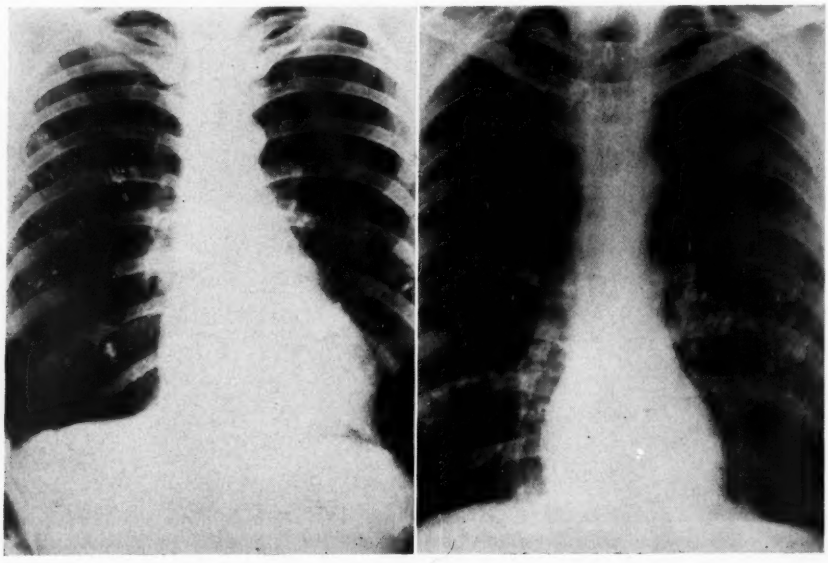
Fig. 3.—Lipiodol granuloma from patient who had received Lipiodol twenty-nine days before surgery. Hematoxylin and eosin (*A*), and brilliant cresyl blue and silver nitrate (*B*).

A.



B. C.

Fig. 4.—Gross appearance of Lipiodol granuloma (*A* and *B*). The focal nature and subpleural location can be seen. The pleural margin on microscopic section can be seen (*C*). Stained with brilliant cresyl blue and silver nitrate.



A. B.

Fig. 5.—*A*, Roentgenogram of patient who had Lipiodol bronchography fifty-six days previously. Lipiodol is concentrated in small, dense foci. Microscopic appearance of granulomas shown in Fig. 2. *B*, So-called "alveolar" distribution of residual Lipiodol in chest x-ray film of patient who received intratracheal Lipiodol 108 days previously. Small focal Lipiodol granulomas were found in the left lower lobe.

Lipiodol 109 to 29 days prior to operation. The lot numbers of the Lipiodol used was available in two instances. Lipiodol from two different lots had been used. Several other patients in the series had received Lipiodol from these two lots and showed no granulomatous lesions. Preoperative chest roentgenograms were available in four of these patients, and evidence of residual Lipiodol could be demonstrated in all. Its appearance varied from that of small dense radiopaque foci to the usual so-called "alveolar" distribution of residual Lipiodol (Fig. 5).

In seven specimens Lipiodol could be demonstrated in droplets concentrated in areas of nonspecific organizing pneumonitis. Here the appearance did not suggest that of a foreign body granuloma (Fig. 6). Radiographic correlation was possible in six of these cases, and in five the distribution of residual Lipiodol by x-ray examination was diffuse. In one patient in whom bronchography had been performed 295 days before operation, no Lipiodol was apparent radiographically.

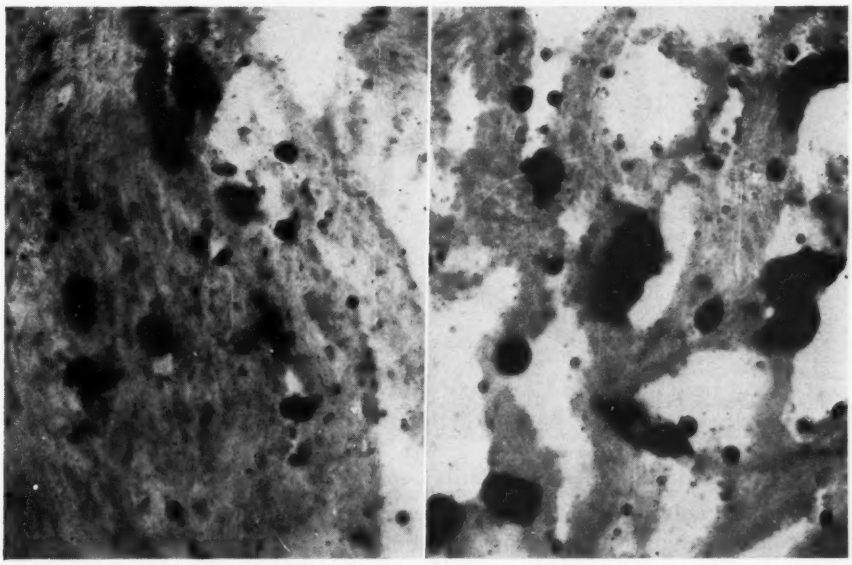


Fig. 6.—Lipiodol droplets concentrated in areas of nonspecific organizing pneumonitis. Specimens from patient who received intratracheal Lipiodol seventy days prior to resection. Stained with brilliant cresyl blue and silver nitrate.

Lipiodol in the lung was found in free or phagocytized droplets in the lumens of alveoli or bronchi or it was involved in one of the cellular responses described above. None was demonstrated in lymphatics or bronchial cartilages. In only two instances was Lipiodol observed within dense fibrous connective tissue applied to the walls of bronchi (Fig. 7), and here interpretation was difficult. Whether the Lipiodol was in lymphatic channnels or in organized lung tissue adjacent to the bronchi could not be ascertained. In

the paraffin sections of the same areas no dilated lymphatic spaces could be seen. Abundant fatty material other than Lipiodol, as demonstrated by the characteristic pink color on staining with brilliant cresyl blue, was present in the bronchial walls, cells of the bronchial cartilages, and in areas of organizing pneumonitis, in the latter instance being almost entirely within macrophages. No Lipiodol was found in the examination of lymph nodes from twenty specimens. In seventeen of these twenty lung specimens Lipiodol was demonstrated in the parenchyma.

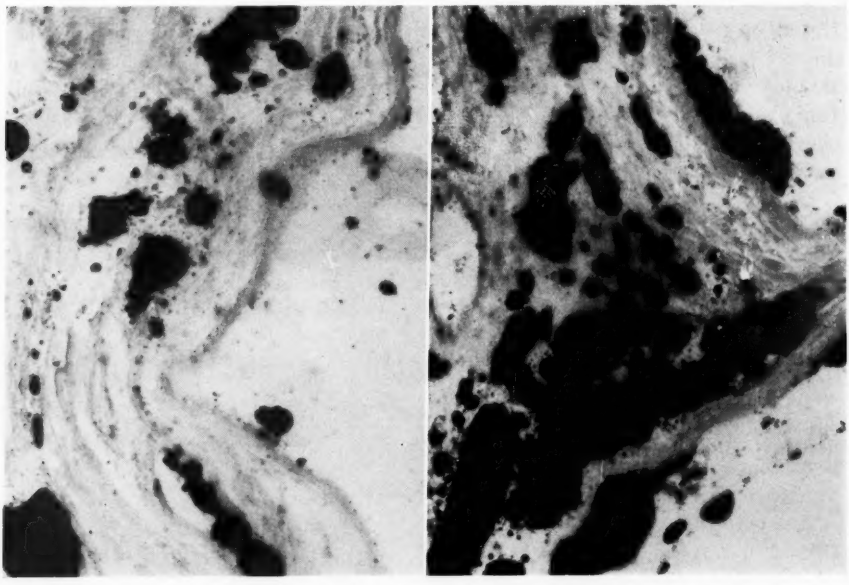


Fig. 7.—Lipiodol droplets in bronchial wall. It cannot be ascertained whether the Lipiodol lies in lymphatic spaces or in spaces within dense collagen adjacent to the bronchus. Patient had received Lipiodol seventy days before operation. Stained with brilliant cresyl blue and silver nitrate.

DISCUSSION

The granulomatous lesions, which were present in 16 per cent of the resected lung specimens and in 26 per cent of those containing residual Lipiodol, were essentially the same as those described in human lungs by Brody,[13] Fortner and Miles,[14] and Storrs and his associates.[15] Their appearance is quite similar to those produced experimentally in the lung by Gowar and Gilmour[12] and in the subarachnoid space by Craig,[22] by Boldrey and Aird,[23] and by Davis and his co-workers[24] by the introduction of iodized oil. The lesions are nonspecific foreign body granulomas surrounding oil droplets which, in the present investigation, were demonstrated histochemically to be Lipiodol.

It is of interest that only a portion of the patients developed granulomatous reactions when all received Lipiodol under similar circumstances. It may be significant that in all of the specimens which contained

Lipiodol granulomas the degree of bronchiectasis was rather slight, and bronchiolitis and pulmonary emphysema were prominent features. There is some radiographic evidence that Lipiodol is retained longer in emphysematous regions than in regions of normal lung or large bronchiectatic sacs (Fig. 8). One reason for this is that emphysematous tissue may be connected by very narrow or partly obstructed bronchi with the proximal air passages. Thus the element of abnormal peripheral retention of Lipiodol may predispose to foreign body reaction.

In the seven specimens in which Lipiodol was concentrated in areas of organizing pneumonitis the localization was probably fortuitous; however, such regions may represent sites of subsequent granuloma formation.

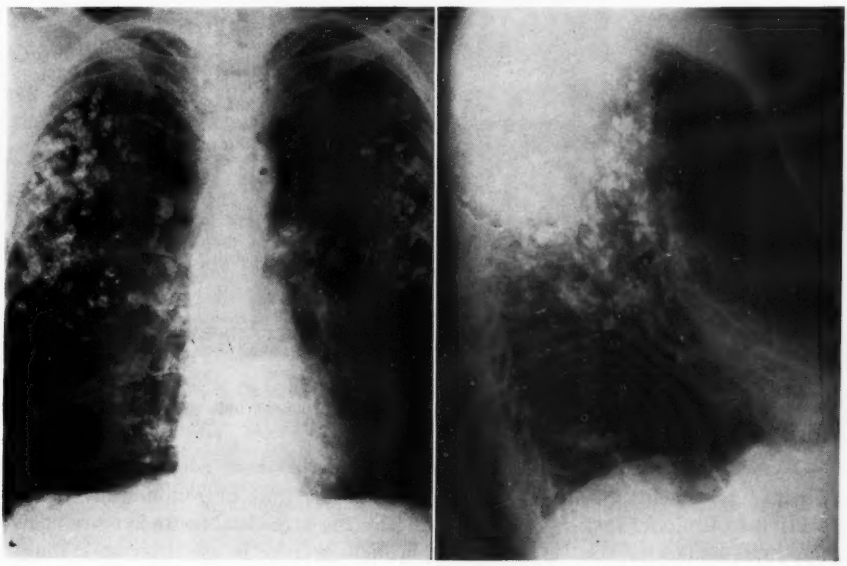


Fig. 8.—Roentgenograms of a patient with bilateral lower lobe, middle lobe, and lingular saccular bronchiectasis forty-eight days after Lipiodol bronchography. The Lipiodol has largely disappeared from the bronchiectatic areas but remains heavily concentrated in the upper lobes which show some emphysema.

In view of the observations made in this group of specimens it seems likely that Lipiodol is not eliminated by way of the lymphatics. Earlier reports of the localization of Lipiodol in the bronchial walls and cartilages were probably based on the observation of fatty material other than iodized oil in these regions. It appears then that Lipiodol in the lung not involved in a particular cellular reaction may be phagocytized, but elimination is entirely by way of the tracheobronchial route.

Lipiodol when protected from the air may exist almost indefinitely without the liberation of iodine. A number of the specimens examined were preserved for as long as four years in a solution whose essential preservative is formalin. Lipiodol protected by a layer of 10 per cent formalin was kept for eight

months without assuming the dark brown color typical of liberated iodine. The oil becomes opaque, however (Fig. 9), and this opacity is probably responsible for the macroscopic appearance of the larger Lipiodol granulomas in the fixed specimen (Fig. 4). The longest period in which Lipiodol remained in the lung before operation in this series was 295 days. Whether the iodine may be liberated with the persistence of free poppy-seed oil in the lung cannot, of course, be stated. However, in the specimens in which Lipiodol could not be demonstrated there were no lesions with the appearance of a lipogranuloma, although lipid material could often be readily demonstrated.

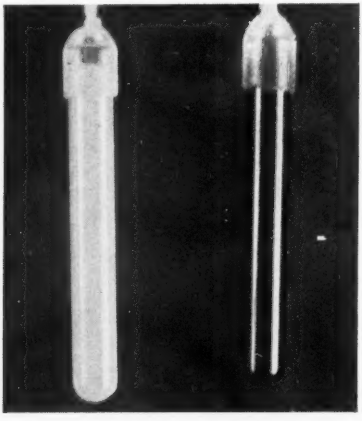


Fig. 9.—Tubes containing Lipiodol. Tube on left was covered by a layer of 10 per cent formalin for eight months, and the Lipiodol has become opaque but not discolored as the Lipiodol on the right which was exposed to the air.

Whether the Lipiodol granulomas demonstrated here are of clinical significance is difficult to state. It seems, however, that granulomatous tissue reaction to Lipiodol instilled into the lung by the bronchial route is more common than generally suspected. Since bronchography is essential as a diagnostic procedure the elimination of the use of Lipiodol could hardly be recommended. However, the search for a more suitable contrast medium must continue, and Lipiodol in the meanwhile be used with the realization of its potential hazard.

SUMMARY AND CONCLUSIONS

Thirty-seven resected lung specimens from patients who had undergone previous Lipiodol bronchography were examined histologically by a method which differentially stains Lipiodol. In twenty-three of these resected specimens residual Lipiodol was demonstrated, the patients having received intratracheal Lipiodol 23 to 295 days prior to operation. Radiographic evidence of retained Lipiodol correlated very closely with the histologic demonstration of the material. In 16 per cent of the lung specimens examined and in 26 per cent of those specimens containing residual Lipiodol, focal, peripheral foreign body granulomas surrounding Lipiodol droplets were observed. In eight

specimens, concentrations of Lipiodol in areas of organizing pneumonitis were found. The development of such granulomas may be related to abnormal retention of Lipiodol in emphysematous regions.

Lipiodol when not involved in a granulomatous process lies in droplets free or phagocytized in alveolar and bronchial lumens. There is no evidence of localization of Lipiodol in lymphatics, in lymph nodes, or in bronchial walls or cartilages. The elimination of the oil is probably entirely by way of the tracheobronchial passages.

It appears that granulomatous reaction to retained Lipiodol in the lung is more common than is generally realized, and the search for a more suitable contrast medium should continue.

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In Memoriam

ADRIAN VANSINDEREN LAMBERT
1872—1952

Dr. Lambert was born in New York on June 30, 1872. He graduated from Yale University in the class of 1893, A.B., and from the College of Physicians and Surgeons, Columbia University, New York, in the class of 1896, M.D. He served as an intern at the New York Hospital; during his service there, in the course of a surgical operation, some pus entered his right eye and necessitated its removal. In spite of this great handicap he went ahead with his training in surgery and succeeded so well that he became one of the leading surgeons in New York City. In the early days of his surgical career, he worked at the Roosevelt Hospital and the Vanderbilt Clinic. Later he was appointed an attending surgeon at the Presbyterian Hospital and was Director of Surgery in that institution during and after World War I.

Adrian VanSinderen Lambert
1872-1952

In June, 1920, he resigned his position there and was appointed Visiting Surgeon to the First Surgical Division of Bellevue Hospital, where he became one of the pioneers in the relatively new field of thoracic surgery. He worked in close association with Dr. James Alexander Miller and with him developed the Thoracic Surgical Service at that institution. This was opened in 1937 as a separate Service in a separate building with its own operating facilities and its own resident staff.

From 1920 until the time of his death on Oct. 15, 1952, he held a position as Clinical Professor of Surgery on the Faculty of Physicians and Surgeons, Columbia University, New York. He contributed many articles to the literature dealing with general and thoracic surgery and in 1914 described a method for the operative treatment of the large sigmoid type of esophagus as seen in achalasia of that organ.

Dr. Lambert was a founding member of the American Association for Thoracic Surgery and served as its president during 1939 and 1940. He took an active part in the annual meetings in the presentation of papers and in discussions.

He was completely devoted to his family. His wife was the former Miss Mary Robinson of Hartford, Conn. They had four children, the late Mrs. Mary Lambert Carden, Adrian Lambert, John Trumbull Lambert, and Mrs. Ruth Lambert Preston. Both of his sons are now practicing surgeons in New York, and Adrian Lambert is a member of the Association.

He enjoyed fishing and sailing and maintained a lively interest in ornithology. In New York City, he was a member of the Century Association and the Yale and Union Clubs. An omnivorous reader, he had an extraordinarily orderly mind, a keen sense of humor, and a goodly store of sarcasm, which he used on his resident staff whenever he considered it necessary for their good. He was an excellent teacher and all those who had the privilege of serving under him knew his courage, his operative ability, his rare surgical judgment, and his sound teaching of surgical principles.

He was a most loyal and devoted friend and generous to a fault with his close associates. With his fertile mind he was always a great stimulus to them and enjoyed helping them with their problems whenever the opportunity offered.

Frank B. Berry